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SOME ASPECTS OF POPULATION MAPPING

by

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ABSTRACT

This is a study of the problems of some of the statistical mapping techniques of population distribution and density.

Initially, all the important basic problems such as population distribution patterns, map scale, map projections, map symbols and optical illusions are investigated, as they are integral parts in designing population maps.

Theoretical and methodological discussions have been made on the general aspects and specific problems of dot mapping, choropleth mapping and isopleth mapping when they are used in presenting statistical data of population distribution and density.

A collection of sample maps showing the population distribution and density in Census Division No. 11, Alberta has been compiled from the 1961 Canada Population Census. These illustrations are used as a basis for analysing the important problems studied. Also, the analysis will lead to an appropriate and logical mapping technique by which the urban and rural population can be delineated with equal success, and the characteristics of the population data revealed.

Finally, a population distribution map of Alberta has been compiled according to the specifications of IGU obtained from Dr. A.L. Farley at the University of British Columbia.

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CONTENTS

LIST OF MAPS

"It is well known that there are many geographical matters which are better presented pictorially, cartographically, or diagrammatically than verbally. Hence it is just as important to study the proper and effective use of various forms of graphic presentation, as it is to study the values of different methods, treatments, grades, and forms of verbal presentation"[1]

- W.M. Davis -

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[1] W.M. Davis, "The Colorado Front Range," A.A.A.G. I, 1911, p.33.

INTRODUCTION

Practically no other means, whether verbal or textual, are as effective as maps in depicting the spatial distributions and relationships of phenomena, both natural and cultural, on the earth's surface. Maps convey information in a clear and vivid way which can easily be grasped and comprehended. Even though air photographs and mosaics have been extensively employed in geographical work during recent decades, they are by no means a satisfactory substitute.

Maps have long been used by economists, historians, geologists and statisticians in their research and investigations. More important still maps are essential tools to geographers, since their discipline is a science of distributions and relationships of earth phenomena. Maps enable them to compare, analyse, interpret and correlate different patterns, and thus help to bring to light many hidden geographical facts and concepts. Conversely, cartography is closely akin to geography; for "it is essentially a technique designed and existing for geographical data."[1] Also Philbrick states that "geography without cartography would be a weak subject, cartography without geography is weaker still."[2] Evidently a better map can be effected if the cartographer is equipped with a significant amount of knowledge in geography.

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[1] A.H. Robinson, The Look of Maps, The University of Wisconsin Press, 1952, p.21.

[2] Allen K. Philbrick, "Toward a Unity of Cartographical Forms and Geographical Content," The Professional Geographers, Vol. 5, No. 5, September, 1953, p.12

It can be said that recent decades have witnessed the rapid progress in the development of cartography since the rediscovery of Ptolemy's work in the Western World during the fifteenth century. This is attributed mainly to the rapid accumulation of knowledge of our globe through numerous sea voyages and explorations on land; a fast development in mapping technology, and an increasing demand for maps during the two World Wars. Thus this rapid advancement provides a large amount of base maps for thematic mapping. In this new era, cartographers are able not only to map their own planet, but also its satellite--the moon. Automation has reached such an extent that maps can be produced directly and very quickly by electronic computers and punch-cards. Nevertheless, we should be aware of the fact that countless problems, especially in the field of statistical mapping, still remain as a challenge to cartographers today and in the future, despite the tremendous effort which has been and is being expended to solve them. There is still a vast frontier awaiting the cartographer's exploration and investigation. Basically, the problems involve the use of map projections, the choice of map symbols and mapping techniques, the generalization of different map elements and the design of maps.

The advantages of graphic presentation of statistical data are obvious. It is far more appealing visually than a mass of inert figures. From such a comprehensive picture all relationships can be readily appraised which facilitates interpretation and analysis of problems within a short period.

In the history of cartography, symbolized representation of statistical data is a relatively modern invention. It was within the

the decades of 1835-1855 that nearly every technique now being used for mapping population distribution and density was derived.[3] All these devices have been brought into active use since the beginning of national censuses in Europe in the early nineteenth century. Ever since then the popularity of population maps has increased on account of their usefulness and wide application.

As maps are media through which information and ideas are conveyed from the map-compilers to the map-readers, so the most essential quality of a good map lies in its effectiveness in such communication. In other words, a successful presentation is able to create an immediate and concrete image of the information being portrayed in the map-user's mind which in turn enables him to make a quick and precise interpretation. Such a map often possesses the inherent characteristics of simplicity, accuracy and aesthetic beauty. These qualities can only be achieved through the cartographer's skill in generalizing and amplifying his data, his acumen in choosing the most appropriate symbols, colours and patterns from a multitude of graphic forms and methods, his artistic insight and talent in map-designing, and his faith in the work. Besides a good map cannot be produced without the cartographer's awareness of the limitations and weaknesses of maps. In reality, imperfections do exist in map data, map projections, map scales and various cartographic techniques which may affect the reliability of the information portrayed by this representation. Therefore, it is the map-maker's goal and task to improve these inherent defects in order to create a more accurate picture through maps.

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[3] A.H. Robinson, "The 1837 Maps of Henry Drury Harness," The Geog. Journ., Vol. 121, 1955, p.440.

Practically all aspects of population are mappable. The general distribution and density of population, population structure, population changes, ethnographic distribution, population potentials and others can be symbolized and portrayed on maps. The employment of different techniques such as dot maps, cartodiagrams, choropleth maps, isopleth maps, maps of extent, pictorial maps, and maps using the dasymetric technique and the chorochromatic technique is hence applicable. In this work the focus of attention is primarily on the study of four basic cartographic methods: (1) dot mapping, (2) dot mapping combined with cartodiagrams (proportional circles, graded symbols, cubes and spheres), as applied to the problem of mapping population distribution; (3) choropleth mapping or cartogram and (4) isopleth mapping to population density.

This work also contains (see Appendix F) the Alberta Population Distribution Map (1961 Census). The map is at 1:1,000,000 scale and it was prepared following the prepared specifications of IGU.

CHAPTER I

BASIC PROBLEMS IN POPULATION MAPPING

Population Distribution Patterns

In mapping population distribution and density, no doubt, the actual spatial arrangement of human beings over the earth surface is the first and the most vital factor to be considered. Its extremely variable distribution pattern and highly dynamic nature in terms of movement and growth have posed serious problems in the field of demographic cartography. These not only have important bearing upon the choice of map symbols and mapping methods, but also affect the accuracy of the depictions.

Despite his ability to multiply at an alarming rate, man is extremely unevenly distributed over the earth's surface even in the more populous parts of the world such as Western Europe and Eastern Asia. Generally speaking, there is a strong tendency for people to cluster in areas with promising economic potential where they can actively engage in agricultural, commercial and industrial activities. The ecumene[1] embraces lands with equable climate, fertile soils, favourable terrains, and abundant mineral and energy resources. These areas are mainly industrial and metropolitan centres in the Occidental world and fertile river valleys in Africa and the Orient. On the contrary, the non-ecumene,[2] or land unoccupied by people or very thinly populated refers to the world's vast tracts of hot and cold deserts, swamps, jungles, ice-caps and great mountain complexes. These voids of human habitation offer man

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[1] Finch, Trewartha, Robinson, Hammond, Elements of Geography, 4th edition, McGraw-Hill Book Co., 1957, p.511.

[2] Ibid.

an unfavourable environment for settlement and a severe challenge. They may be only very sparsely inhabited even though they have significant economic potential in the form of the presence of large oil, uranium or gold reserves. Drastic changes in the distribution pattern are also evident on a regional scale which can produce sharp changes in the density of population between the metropolitan centre and its rural hinterland. In these respects, the cartographer has to devise appropriate symbols to map these sharp contrasts and changes.

Another difficulty pertaining to demographic mapping is the extremely mobile nature of population, triggered by historical, social, economic and even religious causal factors. People have been migrating since the immemorial times, and this movement is greatly accelerated by the development of an efficient transportation system in this "jet-age". There has been continuous movement both on an intercontinental and intra-continental scale. Also both seasonal, temporary and permanent changes are recorded. During the tourist season the population of a holiday resort can be many times the number of its permanent residents. A mining settlement which had been flourishing during previous decades might become redundant with the closure of the mine and be partially or completely abandoned. Since the Industrial Revolution, the movement of people from rural areas to the urban centres has not ceased. There is too the intriguing problem for the cartographer when he comes to map non-sedentary (often nomadic) groups such as the Indian tribes in Canada and the Arabs in Southwest Asia; for he can never be sure where he should place the symbols representing these people on the map.

Another prominent aspect of the dynamic nature of population is the rate of natural increase. On a world scale this is prodigious. J.P. Cole estimates: "If the present trend continues, then very roughly the total population of the world will have increased four times between 1900 and 2000, from 1,500 million to 6,000 million."[3] The cartographer can never find a chance to keep abreast with these changes since the handling of population census statistics and the preparation of the map need a considerable amount of time.

A thorough understanding of the reliability of the census materials is of prime importance before any attempt is made to convert them into map symbols. They are the raw materials and the maps are the final product; the perfection of the latter depends to a great extent on the accuracy of the former. The map-compiler should consider the degree of conformity of the data with the actual situation. This accounts for the necessity of field checks in some areas. Besides, he should know when and where the people are enumerated, and whether the 'resident population' or the 'present population' are ascertained. Needless to say, the latest census materials should be used to produce an up-to-date map.

Map Projections

The problem of portraying phenomena of the earth's surface on the flat surface of the map has been recognized ever since the spherical nature of the earth became known to man.

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[3] J.P. Cole, Geography of World Affairs, 1959, Harmondsworth, Middlesex, Penguin Books, p.109;

Though a globe map is a true representation of the earth in reduced scale, facts tell the cartographer that it is costly to produce, difficult to handle, and most important of all, it is not ideal for pattern comparison since only a hemisphere is visible at one time. Maps drawn on a flat piece of paper have been found to be a preferable substitute, because they readily eliminate all these shortcomings. All maps are compiled on the framework of a grid system, which is a representation of the imaginary graticules of the curved surface of the earth. They are constructed by employing a geometrical or mathematical device known as a map projection. Evidently, owing to the difference in the geometrical nature of the curved surface of the earth and the flat surface of the map, such transference results in the distortion and deformation of the original picture, which is brought about by a different degree of compression and expansion over the flat surface. Consequently, the geometrical relationship of area, shape, distance and bearing will be changed. Hence there is no map which can give an exact replica of the globe.

To understand the precise nature of map projections is of the utmost importance to both the map-maker and map-user; such an understanding enables the former to make the best possible choice of the device for his map, and the latter to realize the inherent limitation of graphic representation. Careless choice of map projection often leads to misrepresentation of the original picture and thus incorrect information is conveyed to the map reader who will accordingly make a wrong interpretation.

For the cartographer, the choice of map projections is guided by two factors: (1) The size and shape of the area to be depicted, and (2) the use to which the map is to be put. In most cases, population maps are drawn on a small scale and show the various aspects of the phenomenon over a large area. If the population of an entire country is to be mapped, it is important to consider the latitudinal and longitudinal extensions of that country since some projections lend themselves better to showing a territory which has a broad shape than depicting another one with a long north-south extension and vice versa. In mapping population density and distribution the projectional distortions in angular measurement and direction mean very little, but the preservation of area and shape is important. Unfortunately a map projection that retains both area relationship and shape relationship does not exist, therefore a choice has to be made between the two. For maps showing population distribution and density the comparison of patterns is feasible only under the circumstance that their areas are truly represented. Therefore, the quality of equal area must be maintained even at the expense of correct shape. This particular property is the characteristic of equal-area projections.

Map Scale

On account of the tremendous contrast between the size of the earth and that of man, it is impossible to show phenomena on a map without using scale. In all cases, everything depicted on maps must be reduced in size to a varying degree. Therefore all maps can only represent in miniature real objects on the earth surface. However, a pro-

portional relationship must be maintained through the use of scales, otherwise the usefulness of the map would be in question. Generally speaking, the variety of scale can be categorized into large, medium, and small scales, but there are no clear demarcations in value to define exactly their difference. No single map scale will satisfy all requirements, the choice depends on the purpose of the map and the detail to be shown.

Map scale is undoubtedly one of the most important cartographic elements. When compiling a population map, the decision made upon the use of a certain scale, in conjunction with the size of the format previously determined and the area to be depicted, strongly affects the cartographer's judgment in designing the general outlay of the map, handling of the data, choosing the size of the symbols and the values they represent. For example, with a format of textbook size, if a population dot map is to be drawn at a large scale, only a small surface area of the earth can be treated. However, there would be plenty of page space for showing the distribution of the phenomenon in great detail, because the value which each dot represents can be small and its size large. On the other hand, the use of a small scale on the same format makes possible the mapping of a larger region. With this change of map scale, crowding of symbols will increase if their size and value are not adjusted accordingly. This not only reduces the legibility of the symbols, but also the impression created is completely different from the true picture. Therefore, the discordance between map scale, size and value of symbols can cause misinterpretation on the part of the map reader.

Maps of large scale and small scale serve different purposes. In large-scale maps the data can be presented in greater refinement. A higher degree of accuracy can be maintained in the processing of the data and during drafting. Maps of this kind are prepared for detailed study and analysis. Generally speaking, very few population maps are compiled at large scale unless a special purpose is contemplated. Conversely, owing to the physical limitation of small-scale maps, the amount of information depicted must be restricted. Hence generalization of the data to be presented is necessary. Naturally, with the decrease of scale the amount of probable errors will increase. In spite of this defect, small-scale maps, including most of the population maps, have their own merits. Though lacking in detail, these maps do show a broad generalized pattern of the phenomena over a vast area from which the map user can quickly infer interrelationships and make comparisons.

For technical reasons, the scale of the manuscript is usually larger than that of the final map. When the manuscript is reduced, the dots and the lines will be brought closer together and the texture of the areal patterns will be intensified to a different degree. This would induce either the merging of the symbols or the alternation of their visual density in the final map. Hence this cartographic problem must be carefully considered by the cartographer during the compiling stage of the map.

Graphic Symbols

An air photograph is a detailed image of both the physical and cultural features of the earth's surface while a map is a generalized and symbolized depiction. The former may delineate all the details such as rock types, ore bearing outcrops, vegetation, soil types, crop fields and settlements within a single frame; but these phenomena are selected and shown in different graphic forms in maps of various kinds, according to the intention of the map compilers. Far more effort, trained skill, and experience is needed to extract information from an air photograph than from a map in which different phenomena are shown by graphic symbols, and recognition of the features present are facilitated by the use of the key or legend. In air photographs no quantitative data such as rainfall amount and density of population can be shown directly whereas everything is mappable. By means of graphic symbols, a map discloses effectively the spatial arrangements of objects of different kinds. Through it, abstract ideas are conjured up, and tables of inert statistical figures come to life, revealing many hidden facts and allowing the deduction of many concepts.

As a matter of fact, words, a form of symbolic device, are a common means of communicating ideas. But if the subjects delineated on a map by graphic symbols were to be purposely replaced by words, the entire map would probably be overloaded with verbal descriptions. Most important of all, the patterns and relationships of different items will no longer be visually obvious. Consequently, a useful device will be turned into a useless encumbrance.

The conventional symbols allow us to cope with the great diversity of data which mainly fall into two main categories. They are: (1) quantitative data and (2) qualitative data. The former shows the number of features present and the latter their characteristics. These graphic symbols are either in simple geometrical figures consisting of dots, lines, circles, triangles, squares, cones,[4] etc., or in plain pictorial forms very closely associated with the shape of the objects they depict. Map compilers have found it easier to manipulate qualitative symbols than to manoeuvre quantitative ones. In order to map phenomena of different kinds, the compiler needs simply to choose the types of symbol which have the best form association. But to show the degrees of variation in numbers or quantities he has to exercise his judgment on the changes of the size of the symbols proportionally to the change in magnitude of the quantitative values. He has to take into consideration the nature of the data he is working on, for frequently, there are abrupt changes or extreme contrasts in the data. The wide difference between the number of people in a large city and that in the isolated settlements of rural farm areas certainly poses a problem in the sense that appropriate symbols have to be designed to delineate this sharp contrast with fidelity. In this respect, the cartographer's approach rests upon the nature of statistical data.

It has been pointed out previously that point symbols can be differentiated into geometrical shapes and pictorial forms. The former

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[4] Kanji Kagami, "Population map using Conical Symbols," Geog. Rev. of Japan, Vol. 24, 1951, p.324.

are found to be more advantageous than the latter when used in demographic mapping. However, Roudolf Modley, disciple of Olto Neurath, does believe that his little human figures, abstract though they are, enliven the cartographic presentation of data that refer to people in comparison with the circular unit symbols.[5] In general practice, the use of pictorial symbols, no matter how simple and unadorned they are, demand comparatively more space on the map than geometrical symbols, and hence their use is often thwarted by the map scale. In addition, the difficulty of adjusting their sizes to the proportional change of the data constitutes a serious handicap. Conversely, in spite of the abstraction and poor association with the form of the phenomena which geometrical symbols represent, they tend to evoke a concrete image of changes in quantities. In fact, for a population distribution map, the key consideration is the variation of the number of people at different locations, and the map reader knows already what a man looks like! It is the functional effectiveness of the map which should be the cartographer's aim. Therefore he should choose the types of symbolic representation which serve this prime purpose.

With regard to symbols commonly used for mapping population distributions and density, the two dimensional dots represent quantities by their relative size, the two dimensional circles by their

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[5] John Leighly, "Population and Settlement in some recent Swedish Studies," Geog. Rev., Vol. XLII, No. 1, January, 1952, p.135.

areas, the three dimensional cubes and spheres, drawn in perspective to give that special effect, indicate quantities by the volumes. These point oriented symbols are placed at central points such as population centres to specify the distribution of absolute quantities. For line symbols, absolute or relative values are represented by the variable length of bars and the relative position of isopleths. In the latter case, points of equal values are linked by means of smooth lines and their arrangement delineates a gradient of change in relative values. Within the category of areal symbols, both chorisograms (these are merely graded areal patterns bounded by isolines) and choropleths (the quantities or ranges of quantities are shown within units confined by administrative boundaries having no numerical values) depict the differences of relative quantities by the change of the intensity of shading, tones or colours.

The recent trend in statistical mapping indicates that symbols are designed in simple forms but effective in facilitating an immediate visual impression of the general pattern. Frederick E. Croxton and Dudley I. Cowden remark: "Graphs and quantitative maps are useful for giving a quick picture of a general situation, but not of details."[6] So the portrayal of patterns should not be a problem in population mapping.

The basic prerequisites of a good quantitative map symbol are simplicity and effectiveness. Their characteristics, both of a

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[6] Frederick E. Croxton and Dudley I. Cowden, Applied General Statistics, Prentice Hall, New York, 2nd edition, 1955, p.67.

non-visual and visual nature, should be taken into consideration in their evaluations. The non-visual aspects should include the ease of conversion of data into map symbols without using any intricate calculation process. The placement of the symbols on the map should not be time-consuming. Their adoption should have a high degree of efficiency in spatial utilization by which a better balance between the size of the symbols and the scale of the map can be easily maintained. As far as the visual attributes of map symbols are concerned, they should be effective in creating an immediate and long-lasting intellectual response. Thus the dependence on the legend can be kept to a minimum. Such symbols count upon their aesthetic appeal which consists of clarity and simplicity of form. Last but not least, they should possess the quality of being free from geometrical illusion which may otherwise convey distorted information to the eye and the mind.

Optical Illusions

It is extremely interesting to note that there is a current tendency for other non-cartographic disciplines such as statistics and psychology to be applied to quantitative mapping. The concept of optical illusion, practically unknown to cartographers prior to the present century, is now playing an increasingly important role in their field. How people read statistical maps and the amount of information they extract from them constitute the map compiler's main interest; and an increasing number of experiments are being undertaken, endeavouring to reveal these secrets and improve the efficiency of quantitative map symbols.

Generally speaking, people think they perceive things as what they are. For years psychologists have discovered, through numerous tests on visual perception of geometrical figures, that this is no longer true. On the contrary, we do not see things as they are, but as we are; and this even varies among different individuals. M.D. Vernon maintains that "...the percept does not mirror the exact stimulus conditions of the external world, nor is it completely determined by the sensation passing from the sense organ to the central nervous system."[7]

That the perception of forms and patterns is perceived quite independently brings about a dilemma in the designing of quantitative map symbols. There are a number of important aspects which easily lead to illusory perception. They are: (a) colours, (b) patterns, (c) size of symbols, (d) shape of symbols and (e) the arrangement of symbols.

The use of colour is an integral part in graphic presentation today in spite of its high cost of reproduction. As compared with black and white patterns or other graphic devices colours have a much greater visual and psychological impact on account of their evident brightness and sharp contrasts in intensity. Needless to say, except to people with colour blindness, the use of colours in population

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[7] M.D. Vernon, Further Study of Visual Perception, Cambridge University Press, p.257.

mapping is usually an advantage rather than a disadvantage. They greatly accentuate the visual effectiveness and the aesthetic appeal of maps. Some colours are purposely selected by the map-maker when he needs to place emphasis on a certain map element. For example, colours like red and black are utilized to represent the highest value or phenomena of significant importance since these colours are so prominent visually that our eyes choose them readily. On the other hand, the use of colours gives rise to a number of technical problems in statistical mapping. In some cases, colours following the spectroscopic scale are used to represent the grading of quantitative values. Unfortunately this colour scale bears no significant meaning to some individuals. Some persons may have different visual reactions to the change of value of a single colour though they are so carefully graded as to be proportional with the change of quantities. No wonder Lotze remarks that "...colour is an illusion because the colour is 'in us' and not in the outer world when there exists only light of various wave lengths."[8]

Another conventional device is the black and white pattern which poses a parallel problem. Their change in the intensity of shading, as the proportional difference in values and hues of colours, signifies a corresponding change of quantities. In order to avoid any

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[8] Edwin G. Boring, Sensation and Perception, The Century Psychology Series, p.238.

possible visual bias the degrees of shading are graded according to the reading of light meters. Despite such scientific accuracy their values are not perceived as such, nevertheless. Results of experiments reveal that the apparent intensity value of a certain pattern appears to be different when it is matched against another one with a contrasting intensity; i.e., a darker pattern appears to be different when it is associated with another having a much lighter tone and vice versa. The degree of change has never been successfully measured by any available means. Therefore any feasible adjustment is impossible at the moment.

In the field of geometrical illusion there are a large number of variants. The famous Muller Lyer illusion illustrates how two accurately measure lines of equal length appear to be different to us. The Schumann's notable Square and Diamond shows that two equal sized squares would appear different in dimension if one of them is tilted through an angle of 45 degrees. It seems to be bigger than the other. The concept of size constancy is of prime importance in population mapping since a certain size of any two dimensional symbol signifies a fixed quantity. This inconsistency due to optical illusion will tend to mislead the map reader. With the aim to design the best possible map symbols for the most accurate reading of the map, cartographers feel there is an urgent need for basic research on map symbols. Many recent studies have investigated the psychological function for some symbols of geometrical shape, both two dimensional and three dimensional, which are commonly used to delineate population

magnitude. Flannery made an investigation on the visual estimation of graduated circles.[9] His findings show a remarkable tendency for under-estimation rather than correct or over estimation of the relative size values of the symbols. The results are 13 per cent correctly estimated, 12 per cent over-estimated, and 75 per cent under-estimated.[10] This astonishing result, therefore, furnishes an example of the weakness of quantitative maps using such symbols. Another interesting experiment has been made to study the magnitude estimation on volume symbols.[11] Spheres and cubes were used as stimulus materials which served as a basis to find the effectiveness of other volume symbols in general in creating the visual impression as desired. In the experiment a more realistic cartographic environment was achieved by placing the testing symbols on a background scattered with other symbols of smaller size. The result shows that the attempt to use volume cartographic symbols to create the impression of volume as desired is a failure. Few people realize that the doubling of the radius of a sphere would consequently increase its volume by eight times. Though they are drawn in perspective and with the artistic light and shadow effect or with curved graticules which give an apparent feeling of three

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[9] J.J. Flannery, The Graduated Circle: A Descriptive Analysis and Evaluation of a Quantitative Map Symbol, unpublished Ph.D. dissertation, University of Wisconsin, Madison, 1956.

[10] Ibid., p.80.

[11] Gosta Ekman, Ralf Lindman, W. William-Olsson, "A Psycho-physical Study of Cartographic Symbols," Report from the Psychological Lab., The University of Stockholm, No. 91, February, 1961.

dimensionality, they are only estimated as to the geometrical area occupied by the symbols. Mathematically, the volume symbols are a space-saving device on maps, but visually, the values represented by these symbols are usually not correctly estimated.

One may easily overlook that the distribution pattern of cartographical symbols may result in an illusion of their size. They look different under different 'environmental' conditions. Birch observes:

> "Even when a map is produced with dots uniform in size, shape, and value, and accurately distributed, it does not of necessity give a correct visual impression. A given number of dots in a certain area looks less dense when surrounded by areas with many dots than when surrounded by areas with few dots. In other words, dot density appears to vary inversely with that of surrounding areas."[12]

Illusion of this kind is not confined only to dots, but similar effects can also be observed on maps with quantitative symbols of large size. Two circles of equal size may look different if one of them is associated with several circles of larger size and the other is standing by itself.

Owing to all these frailties in visual perception, no matter how accurately and precisely the map symbols are constructed, they are not always accurately read by the map users. The investigation of the problem of optical illusion indicates that some of them are remediable,

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[12] T.W. Birch, Maps - Topographical and Statistical, Oxford Press, 1952, p.155.

but many of them are still beyond the possibility of rectification. The cartographer can avoid using squares and tilted squares on the same map, but it is beyond his power and knowledge to influence the 'human factors' which cause the size variation of symbols under different circumstances. One may make the following query. When designing the quantitative symbols should the map compiler aim for maintaining a mathematical accuracy or conveying a correct visual impression? He has to sacrifice one or the other. Strictly speaking, this question is still unanswered today. Thus this special problematic area offers a wide frontier for future research and investigation. However, at present, the best adjustments can be made through preliminary experiments. Symbols of different form and arrangement set in 'natural cartographic environment' should be used as experimental stimuli and apply among groups of individuals having different academic background and cartographic experience. By this means, a more satisfactory result can be obtained.

CHAPTER II

CARTOGRAPHIC METHODS AND THEIR DESIGN PROBLEMS USED FOR SPECIAL MAPS

Population data can be expressed cartographically by means of either the absolute or relative method, the choice depending entirely upon the purpose intended. The former method generally supplies not only the locational information and the magnitudes in absolute numbers of the phenomenon but also depicts the patterns of grouping and arrangement. The latter way shows the average number of people inhabiting a certain areal unit of land, or expresses the changes of the density values.

The maps compiled by the absolute method, discussed in here, are the point symbol maps--dot maps with or without other associate point symbols (dot maps or dot maps in combination with cartodiagrams). Those compiled by the relative method fall into two main categories: (a) areal symbol maps - choropleth maps and (b) line symbol maps - isopleth maps. Their presentation, of course, calls for different map symbol designs and mapping techniques. The problems arising therefrom are varied.

Absolute Method

The Dot Maps - General Aspects

This category of cartographic representation of population data embraces primarily maps using spot symbols such as dots and other point symbols of geometrical designs. In reality, the distribution of population is extremely sporadic even within a small area. These symbols, having a point orientation, can easily be applied to imitate the actual situation of the units of the distribution patterns. A person or a group of persons

being a distinct entity or constituting non-continuous units can best be represented by these discrete markings.

Considering all the existing point symbols, dots are the most simple in form yet extremely successful in presenting an explicit picture of population distribution. They easily arouse an immediate visual and intellectual response on the part of the map users. As Balcher and Lewis remark: "The dot is definite, graphic and pictorial for portraying the distribution of population."[1] This statement is probably justified by the common use of this point symbol. According to Flannery's investigation on the frequency of use of different types of cartographic symbols, the dots range up to 31 per cent, the highest of all.[2]

Besides its simple appearance and functional effectiveness, the dot map has many other merits. It offers different visual impressions at different scales. A small-scale dot map reveals a broad pattern of the dispersion and concentration of population. The varying degrees of grouping of the symbols give a crude picture of population density variations due to the disparity of tonal density which they create, though the dot maps supply information concerning the absolute number of population. On the other hand, on a large scale, a dot map allows the true depiction of the geographical location of groups of inhabitants or even of individuals.

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[1] W.G.V. Balchin and W.V. Lewis, "The Construction of Distribution Maps," Geography, Vol. 30, 1945, p.91.

[2] J.J. Flannery, The Graduated Circle: A Descriptive Analysis and Evaluation of a Quantitative Map Symbol, unpublished Ph.D. dissertation, University of Wisconsin, Madison, 1956.

Several types of dot maps are in common use in showing population distribution. They are maps with (a) dots of uniform size, (b) dots of different sizes and (c) dots of graded size and modified shape. In maps of the first kind the size of the dot maintains a uniformity over the entire map and each represents a definite numerical value. In reality, there is a considerable diversity in population distribution even in rural areas. One can find scattered individual farmsteads as well as small agglomerations. In order to map these variations with equal success, dots are made in graded sizes representing the different ranges of quantities. This is comparable to coins of different sizes denoting different values. Hence this method is known as the coin system in population mapping.[3] It can be used with great advantages since the number of people in any locality seldom correspond exactly to what a dot represents no matter what value has been assigned to it. If the sizes of the dots are adjusted to represent the various steps of quantitative value, they will be able to cope with statistical data having a great range of magnitude. For even easier visual discrimination the dots are modified in shape. They are sometimes printed in two or three different colours to differentiate the characteristics of population. These modifications inevitably make the visual evaluation and comparison of the symbols much easier and quicker even with a cursory glance. The population distribution map of the United States published in 1963 furnishes a good example.[4] The colours of red and black differentiate non-urban conglom-

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[3] Sivaprasad Das Gupta, "The Coin System in Population Mapping," Geogr. Review of India, 22, 1960, p.34.

[4] Map of Population Distribution, urban and rural, in the United States, 1960. Prepared by Geographical Division, Bureau of the Census, U.S. Department of Commerce.

eration and dispersed rural population while their magnitudes are represented by the different forms and sizes of the symbol.

Another type of dot map differing from the conventional ones is the multi-colour dot map. Its advantages are obvious. The aesthetic quality of the colour dots creates an effect of 'brightness' - the quality which is lacking in black and white illustrations. This is also the best device to show the distribution of a population consisting of different races or ethnic groups. When designing colours to be used for the dots, two basic considerations should be taken into account. The dots should be vividly distinguishable from the background and the colour of the individual dots must possess a good contrast in order to aid easy differentiation among them. Unfortunately, the merits of colour dot maps are offset partly by the high cost of reproduction and most vital of all, by the high probability of inducing a new colour. For example, the colour of purple will be seen in the area with red and blue dots. Many tests are being conducted in an endeavour to keep this defect to a minimum.

Sten de Geer is the pioneer in using three dimensional point symbols in dot maps.[5] In his population map of Sweden in 1917, at the scale of 1:500,000, the spheres stand for the large concentrations of population in the cities. These symbols inevitably create a good graphic effect since they are drawn in perspective, assuming the light comes from the northwest and shadow appears on the opposite side of the spheres.

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[5] L.E. Travener, "Population Maps: Problems and Methods of Demographic Cartography," Genus, Rome, 12, 1956, p.94.

Furthermore, they are perhaps the most economical in space utilization, since their dimensions are obtained from the cube root of the total number of people in any of the cities.

Another variant of dot map is the one in which a dot, instead of representing a certain absolute value, delineates a percentage of the total value of the distribution. This method was designed by J.R. Mackay.[6] For the sake of convenience, the map often bears either 100 dots or 1,000 dots; each dot will then show either 1.0 or 0.1 per cent respectively of the whole quantity. From a percentage dot map, one can easily grasp the information on percentage, proportions and fractional distributions. It also affords a clear relationship between the individual dots and the total number of dots on the map from which an ideal arithmetic comparison of one part with another can be made. For this particular type of dot map, the dot size must be chosen in such a way that everyone of them is clearly distinguishable from the other. Any coalescence of dots will cause difficulty in the comparison. The processes of converting statistical data into symbols is time consuming, because to obtain the percentage a certain number of people in each locality or administrative unit must be compared with the total value each time. Obviously, this method is not suitable for depicting a large amount of statistical data in a single map.

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[6] J.R. Mackay, "Percentage Dot Maps," Econ. Geogr., 29, 1953 pp.263-266.

Special Design Problems

Assuming that when designing a dot map, the cartographer determines the size of the map symbol rashly, chooses its value carelessly and inserts them in place blithely, one may wonder about the amount of misinformation transmitted through this graphic medium. In fact, it is beyond doubt that only through painstaking effort, great patience, and intelligent approach can these interrelated problems, upon which the success of the map depends, be solved.

From the standpoint of considering accuracy as a measurement of the effectiveness of a dot map, another difficulty arises. There is a choice between mathematical precision and visual accuracy, since to harmonize both is impossible. The latter, nevertheless, should be a better choice, for a map is essentially a visual representation of phenomena and serves mainly for illustrative purposes. Hence the design of dot size, dot value and dot placement cannot be determined by mathematical formulae but only by the visual judgment of the map compiler.

The Dot Size

On two maps of similar scale and dimension, the variations of the dot size, providing their number is equal, and their arrangement similar, will give an immediate impression of visual tone density change. A well chosen size will give balance as well as contrast to the cartographic representation by which the characteristics of the distribution are portrayed without distortion. Therefore its predominant importance is evident.

Ideally, the size of the dots should be proportional to the area occupied by the people and the number they represent. The difficulty of

maintaining this proportion increases with the decrease of map scale; also, on account of the extreme variation of number of people in different localities, this absolute proportion can hardly be attained in actual practice.

In a comparative sense, on a wall map, the size of the dots should be larger than those in an atlas map even though they have identical value denomination. The adjustment of the dot size in this case is made according to the distance from which they are viewed.

The dimension of the dots should be approximately inversely proportional to their number if a good balance and equal contrast in tone density is to be maintained. The larger the number of dots, the smaller their size should be and vice versa.

If the dot size is not well adjusted to the map scale and the number of people each represents, that is, when their size is too large, coalescence will be unavoidable in areas of concentration. On the contrary, if it is too small, empty voids will be abundant leading to a lack of contrast. This will destroy the graphic effect of the map.

J.R. Mackay, on the assumption that the dots are to be placed uniformly over the statistical units, has devised a nomograph[7] from which information on dot size, number, their separating distance and the aggregate area of dots per square inch can be readily obtained. From that graph the most appropriate dot size can be chosen provided the number of dots per square inch is known, and coalescence of dots can be avoided. For example, if there are 300 dots in a square inch, their diameter is

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[7] J. Ross Mackay, "Dotting the Dot Map," Surveying and Mapping Vol. 9, No. 1, January-March, 1949, pp. 3-10.

0.02 inch; the distance between them will be 0.04 inches and the aggregate area of the symbols occupied 0.1 of the square inch. So if that number of dots is made according to the size chosen above, there would not be any danger of coalescence. But suppose with the same number of dots, the diameter increases to 0.05 inch; the coordinate will be in the zone of coalescing dots. In general practice, the dots are seldom placed uniformly with a definite distance separating them; instead, dots representing population are located as near as possible to where the people exist.

An experienced cartographer will first determine the dot value in accordance with the map scale, the nature of the data and the purpose of the map, then, by means of a series of trial and error experiments he can decide, with more satisfactory results, the size of the symbol to be drawn on the map.

The Dot Value

At the initial planning stage of a dot map, the map compiler has to assign a value to the dots, indicating the number of persons each map symbol represents. Before he makes any decision in his choice he has to weigh the following essential factors; (1) the range of the statistical data, (2) the map scale and (3) the amount of detail desired. Theoretically, the smaller the value the dot represents, the more detail the map will depict. This is often limited by the nature of the distribution and the scale of the map, over which the cartographer has very little or no control.

Balchin and Lewis maintain that the success of the map depends

on the right choice of the value to be accorded to each dot.[8] The characteristics of the diversity in the distribution would not appear if the dot value is chosen at random. The map will be an overgeneralized picture if the value chosen is too large, especially in large-scale maps. Even in the thickly populated areas the dots would stand too far apart and scantily populated areas would appear to be featureless on the map. But if the value assigned is too small, though it might sometimes show the scattered rural population adequately, in the densely inhabited areas the dots tend to fuse together into a solid black mass. This would make impossible even a rough estimation of the population present. The visual comparison of population magnitude at different localities would be handicapped. Hence it is undesirable when the value represented is either too large or too small. No doubt, it would be most ideal to choose a value which can represent with equal success the population in great cosmopolitan areas and those in rural ones. Yet in practice this goal can never be achieved, for population statistics are usually extreme at both ends of the scale. Many attempts have been made to solve this problem either by varying the size and shape of the dots to represent different ranges of value or by using other point symbols whose dimensions can be made proportional to the quantitative data. The latter method is very successful in eliminating the possibility of dot coalescence in large urban areas. Another remedy to this problem is the use of inset maps compiled at larger

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[8] W.G.V. Balchin and W.V. Lewis, op.cit., p.90.

scales as compared with the original version. In the inset map more dots can be placed without uniting together, hence a clearer picture of the congested areas can be depicted with the dots still representing the same value. The congested areas on the small-scale map should be filled with dots, so that comparison with other areas is still feasible.

Ordinarily, except in very rare cases, the statistical number in any administrative unit does not equal exactly the quantity or a simple multiple of the quantity represented by the dot. For example, if x units are assigned for one dot, it often happens that one dot has to represent either $x + 1/2x$ or $x - 1/2x$ units. These probabilities of quantitative errors of $\pm 1/2x$, may be termed operational errors.[9] If the frequency of empty voids in the actual distribution is low within a large area, the cartographer, when assigning the number of dots to each administrative unit, should take into consideration the residual values left out in the neighbouring units; an additional dot can then be placed in the vicinity if the sum of residual values approaches x. By this means the percentage of operational error can be minimized.

To ensure a more satisfactory choice of dot value, a reconnaissance survey of the nature of the distribution and preliminary experiments are indispensable. The extremes in the statistics should be noted. Various tests should be given to any chosen area preferrably with densely populated urban centres and widely separated rural settlements. Consequently, a more precise visual impression of the distribution can be created.

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[9] Sivaprasad Das Gupta, "Cartographic Limitations of Maps," Geogr. Review of India, Vol. 23, No. 2, June, 1961, p.60.

Dot Placement

After the dot value is decided and its size chosen, the cartographer has to place it on the map. He should strive to place the dots as near as possible to the geographical locations of the population. For large-scale maps there seems to be little handicap in inserting the dots close to the actual point of distribution since the unit represented by each symbol is reasonably small and there is ample room at the disposal of the map compiler. The difficulty will, however, increase considerably in accordance with the decrease of map scale and an increase of the dot value. Under such circumstances, the most recommended method would be to place the dots near to the centre of gravity of the distribution. In such an operation the cartographer has to exercise his judgment to determine the location of the dots.

There is always a close link between the distribution of population and the spatial arrangement of their settlements. Hence topographical maps, preferably of large scale, which often carry information of the location of the human dwellings, will be an indispensable aid in dot placement. Another important tool is air photographs. Again, the scale must be sufficient for rural farm buildings to be clearly discernable. When these are not available, other devices such as land use maps, soil maps, climatic maps, and road maps can be profitably used, since there is a tendency that people settle on land with favourable terrain, equable climate, fertile soil and convenient transport facilities. On the contrary, they tend to avoid swamps, muskegs, rugged moraine country and sand dune areas. These would probably appear as voids in population

maps. Of course, such placement would be very subjective. It depends solely on the cartographer's estimation. But if he has a good knowledge of the area which he may procure either from relevant literature or field checks, the gaps between the results he obtains and the real situation will be closed to an appreciable degree.

To place dots in an even pattern is by no means a new method nor a recent practice. In De Geer's Population Map of Sweden in 1917, the dots representing large towns below the densely populated urban category are arranged uniformly and the shapes of the areas occupied by the dots correspond closely to the actual extent of the settlements. The areas, in comparative scale, may or may not equal to those enclosed by the settlement boundaries, however.

When necessary aids are not available to help the insertion of dots, especially in rural areas, the best alternative would be to set the dots uniformly within the administrative units. Each dot is then kept equidistant from the neighbouring dots and the distribution is made as even as possible inside the census unit: hence the population is assumed to scatter uniformly. Obviously, this will not give a true picture of the distribution; instead, it only supplies an impression of the apparent density. This method is not highly recommended if the areas of the statistical units are too large, the lack of contrast will only result in a very crude depiction. Therefore the size of the administrative unit is the vital factor which determines the degree of refinement of the method.

Relative Methods

Choropleth Maps (cartograms) - General Aspects

The dot map is essentially a cartographic depiction of the distribution of absolute number of population or other quantitative values. The choropleth map, by using quantitative areal symbols, can be made to show the spatial arrangement of derived values, such as population density. Conventionally, population density is expressed in a simple arithmetic ratio denoting a stated number of people per unit area of land. As the population data are enumerated within some pre-determined census tracts or administrative subdivisions, the entire territory is taken into account in the computation of the density value. Also, these units are chosen as 'control space' for symbolization. "Choropleth has already gained some currency as the designation for an areal symbol bounded by the limit of political or other statistical subdivisions of the area mapped."[10]

However, when the above points are compared with the actual situation, there is a marked degree of discrepancy. First of all, the way that population density is expressed simply as a direct relationship of the number of people and area of land is extremely misleading. When these data are represented cartographically, the resulting picture would probably show something which departs from the real pattern. Secondly, it is a salient fact that the distribution pattern of population is extremely varied, so too is its density (see Appendix A). However, in population density maps using the choropleth method, the tonal uniformity

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[10] J.K. Wright, "The Terminology of certain Map Symbols," Geogr. Rev., Vol. 34, October, 1944, p.653.

of the areal patterns implies an even distribution of values. Thus the statistical surface of a choropleth map will be a series of step-like horizontal planes. The actual variations in density are generalized. Consequently, many local details are concealed and characteristics obliterated. In other words, the 'highs' are levelled and the 'lows' are reclaimed. Furthermore, the degree of generalization varies with the size of political units. The larger the area, the cruder the picture will be. The following table[11] clearly demonstrates how the different political units affect the density value. It is not suggested that certain units cannot be used for density mapping. The choice should depend on two important factors: (1) the map scale to be used, and (2) the purpose of the map contemplated. However, much refinement is still desirable.

TABLE I

Areal Unit		Land Area (sq. mi.)	Density
Chicago	census tract, No.550	0.024	91,300
"	community area No.35	1.623	48,500
"	city	207.5	17,450
"	urbanized area	638.0	7,713
"	metropolitan area	1,184.2	4,283
"	standard metropolitan area	3,617	1,519
Economic sub-region No. 64		7,328	958.7
East North Central Division		244,867	124.1
Continental United States		2,974,726	50.7

[11] Otis D. Duncan, Ray P. Cozzort, and Beverly Duncan, Statistical Geography - Problems in Analyzing Areal Data, The Free Press of Glencoe, Illinois, 1961, p.35.

Thirdly, choropleth maps may provide a false impression of the distribution pattern of population density, In such a map all the changes of density values are shown to occur only on both sides of the boundaries of statistical units. This may be true along the limits of great urban conglomerations; but there may also be a marked difference in population density at the boundary separating two physiographic regions, for example, an unproductive sand plain and a fertile lacustrine plain. This sharp contrast would even out if they are enclosed within the same administrative unit. On the other hand, any gradual transition which might occur over a vast territory can never be shown on a choropleth map.

Several suggestions have been made attempting to eliminate the above mentioned shortcomings. It would be more realistic, especially when mapping areas of dominantly agrarian economy, if population density is expressed as a certain number of people per unit area of farm land. However, when the map maker comes to map an area of diversified economy, many complications will emerge. He has to evaluate the different economical elements such as resources, labour, capital, amount of production, agricultural productivity and many others before he can obtain the economic density of population. In practice, this is extremely difficult and even impossible.

Some cartographers prefer not to use administrative units in delimiting density areas. J.K. Wright demonstrates in his map of Cape Cod[12] the mapping of population density by means of the dasymetric

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[12] J.K. Wright, "A Method of Mapping Densities of Population with Cape Cod as an Example," The Geog. Rev., Vol. 26, 1936, pp. 103-110.

technique (the term dasymetric means measurement of density). In the method, though the statistical data are still derived from the census tracts, their boundaries are no more significant. Instead, the lines which confine the various density units would be density boundaries. They enclose the different physical and cultural regions such as river valleys and settlements respectively. No density value is to be delineated over most of the sand dune areas, muskegs and rugged mountains which would otherwise be taken as a part of the total area within the statistical unit used in the calculation of population density. In fact, it would be more meaningful to accord the density units as close as possible with the actual distribution patterns of the inhabitants; also when computing population density, all kinds of land and water bodies where no human settlements or human activities can be found are to be excluded. Topographic maps, land use maps and air photographs at reasonably large scale would provide helpful clues in this respect. Field checks may be necessary in some cases. By the aid of the above references, part of the area and densities of population within the unit are estimated, and the density of the remaining part can be derived from the following formula:

$$Dn = \frac{D - (D_m A_m)}{1 - A_m}$$

D is the average density of population of the whole census division. Dm the estimated density in one part of the unit whose area is estimated as Am. The area of the remaining part will be 1 - Am or n. Dn, result of the calculation, is the population density in n. The dasymetric method has at least two distinct advantages: (1) the map shows a more

precise geographical location of the different density categories and (2) it depicts a better man-land relationship which is invaluable for geographical evaluation and analysis.

Special Design Problems

Choices of Patterns

On choropleth maps, colours as well as black and white patterns are the graphical media used to represent statistical data. These are arranged in consecutive groups denoting different ranges of values. The decision made as to the choice of these graphic patterns is extremely important. It will affect the general appearance of the map and hence control its legibility, accuracy and aesthetic beauty.

The grey tone patterns commonly used for choropleths fall into two kinds. One is made up of parallel lines of different widths as seen by the naked eyes, and the other composed of dots of different dimensions. As A.H. Robinson observes, the parallel line patterns tend to cause eye movements and the directions will follow the orientations of the lines. So when viewing a choropleth map which is made up of line patterns, the map reader's eyes will be forced to change directions constantly. Contrarily, the dot patterns are much more stable and will not cause discomfort to the eyes.[13] Therefore it is recommended that the former should not be used frequently. The dot patterns have another merit. The size of the statistical units into which the patterns are to be placed does

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[13] A.H. Robinson, Elements of Cartography, John Wiley and Sons, Inc., 1960, p.232.

not affect their choice. Owing to the fine texture of the patterns, there would be no alternation of their apparent density, no matter what the size of the areas to which they are applied. The line patterns do not possess such an advantage.

It has long been argued whether a completely white pattern should be used to symbolize the lowest value since it has been and is still being used in this way. This area symbol provides, apparently, a high degree of contrast, if it is not used, the scale of tonal changes along the spectrum will be shortened. Hence the degree of difficulty of differentiating such changes will increase. However, psychologically, it conveys to our mind an immediate impression of emptiness. If it is used to symbolize the lowest value in a population map, at the first sight, the area may be interpreted as a population void. Preferably, a light tone pattern should be chosen for such a purpose. On the other hand, the completely black coloured pattern has commonly been used to represent the extreme in a range of statistical data. The choice is logically sound, its tonal value reaches maximum in a whole series of grey tone patterns. Furthermore, the choice is justified by the fact that its maximum tonal intensity yields the strongest impact upon our mind. We would unconsciously visualize that it infers a maximum value in a set of statistical data.

A whole range of grey tone patterns tends to arouse an impression in the viewer's mind that the lighter patterns denote lower quantities, and the darker the tone, the higher the values will be. However, to grade the grey tone patterns into distinctive steps is no simple task; to create an optical impression commensurate with the quantities

they represent is even more difficult. Cartographers have learned from experiments and experience that the degree of contrast in a graded series of grey tone patterns will have important bearing upon their differentiation and comparability. A low contrast in the variation of light and dark along the graded steps will result in a monotonous grey uniformity over the entire map. All the significance in the data will be concealed. From such a map, the map users can hardly make any comparison or visualize any relationship. In effect, such a map is useless. Therefore, attempts should be made to select those patterns which have a sharp contrast.. This will facilitate a much easier differentiation between the neighbouring steps. Each of them will represent distinctly an individual class of statistical numbers. Even at a cursory glance, one is able to see immedicately the distribution of all the choroplethic categories in the graphic presentation. Hence the functional effectiveness of a choropleth map will hinge on the choice of patterns. The findings of the previous experiments indicate that, to our visual sensation, the percentages of the printed area of the matrix do not correspond to the numerical rating. "It has long been understood that the eye is incapable of measuring degrees of grayness which are developed on an arithmetical scale."[14] Our visual response to external stimuli is somewhat subjective. To an individual, some part of the grey scale may be overestimated and some underestimated. To another person, his visual judgment of the same stimuli may be different. So a scale of grey patterns

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[14] William G. Byron, "Use of the Recording Densitometer in Measuring Density from Dot Maps," Survey and Mapping, January-March, 1958, p.42.

chosen by the cartographer's own eyes may not be satisfactory. Fortunately, it has been found out that patterns of a desired percentage of darkness, as appear to the average human eye, can be obtained by referring both to William's curve of the grey spectrum and Jenks and Knos' shaded pattern reference chart.[15] They are derived from the results obtained from experiments applied to different groups of individuals having different cartographic experience and academic background.

Choice of Colour

Colour is a prominent graphic aid to the cartographer. In terms of simplicity and legibility, it is to be preferred to grey tone patterns. When colour is employed for showing quantitative changes on choropleth maps, it is an even more complicated technical problem to design an appropriate grading of visual steps. People may react differently to colour though hues such as yellow, green, blue, orange, purple, and red are matchable with the steps along the grey spectrum. If colour has to be used shading of one colour would be a good substitute. A more precise grading of tonal values can be secured through the use of screens in printing. It is similar to the grey tone patterns only that the white portion is replaced by a hue.

Choice of Class Intervals

No less important than the choice of dot values in designing a dot map is the selection of class intervals in choropleth mapping. Only after a set of population data has been carefully organized, classified

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[15] G.F. Jenks and Duane S. Knos, "The Use of Shading Patterns in Graded Series," A.A.A.G., 51, 1961, No. 3, pp. 316-334.

into intervals and symbolized by appropriate areal patterns does it reveal all the significant spatial relationships and provide a basis for visual comparison. To organize the data into a limited number of class intervals has long been regarded as a cartographic problem in population map design. Owing to the sporadic differences and the extremes present in population statistics it is by no means easy for the cartographer to confine himself to work on a small number of class intervals and yet to present the characteristics of the areal distribution of population density without sacrificing the accuracy of the original data. The different ways of processing a single set of data will give completely different appearances to the final map. A judicious grouping of the data is absolutely essential because this will ensure the conveyance of accurate information to the map users. If the classes are poorly selected, nothing will be emphasized and all the significance in the data obliterated. The map reader hence gains no better impression from it than he would otherwise obtain from the original data arranged in a geographical array. Indeed, he might even be misinformed.

Several systems of progression have been employed to break the statistical data into class intervals. By means of arithmetic progression, the data are divided into groups with their values increasing in regular steps. If the range of value in each step is small, (e.g. 0-5-10-15) the top values can seldom be reached unless a large number of classes is used. The map will then be ruined by excessive detail. But if the amount encompassed in each class is large, (e.g. 0-250-500-750-1,000) many important characteristics which may occur within any of the steps

will be masked. The geometric progression seems to be a better choice; yet the greater proportional increase at the higher end of the scale may level some irregularities of special importance. More often, when dealing with population statistics, a rational system is preferred. This would help to make a more logical selection of class intervals.

Number of Class Intervals

The determination of the number of class intervals like the selection of class limits and the choice of appropriate tonal patterns, affects the appearance of the map. Obviously, a large number will cause technical problems. The more classes to be used the more difficulties the cartographer will encounter in choosing patterns which can be easily differentiated. In addition, the superfluous detail thus created will nullify the effect of the map. On the contrary, too small a number to be used is comparable to over generalization. It will consequently give a crude representation of the population data. Eight shades of grey pattern are about the limit, and consequently the cartographer must be relatively restrained in this respect.[16]

Isopleth Maps - General Aspects

This is another form of graphic representation commonly used for mapping density of population. In a map of this kind, the variations of the values are shown by isopleths as a hypothetical continuum instead of a series of step-like surfaces as in choropleth maps. An isopleth can be defined as a line composed of an infinite number of theoretical points.

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[16] A.H. Robinson, op.cit., p.231.

of equal relationship. In population maps, each of them stands for a certain constant density value. Unlike a choropleth map in another manner, the boundaries of administrative units have no significance and are not shown on the map.

In isopleth maps, the derived values are assumed to project vertically from carefully estimated positions on an imagined datum plane. The smooth running line symbols interpolated with reference to the peaks of these projections infer a three dimensional statistical surface. Thus when isopleths are used to map population density, an assumption is made that the values change in a continuous fashion.

The apparent similarity of isopleth and contour lines leads to an erroneous concept that the patterns of relief on a statistical map and those on a topographical map would appear to be identical. In fact, many of the relief elements such as hills, escarpments, valleys, spurs etc. do exist on a statistical surface, but their peculiar manner of distribution, due to the nature of statistics would be different from those in the natural terrain.

We can easily obtain a concrete picture of the landforms from our contact with the physical environment and the understanding of the combined factors of natural elements and the physical forces and processes which yield the characteristic features on the earth surface. This makes us conscious of the presence of the characteristic features in a certain physical setting and helps us to visualize their patterns on relief maps. In an isopleth map the patterns of the lines and the forms thus created pertain only to the location and the nature of the distribution of the derived values. The assertion of the presence of a

three dimensional surface on a two dimensional medium causes considerable difficulties for the untrained map readers to comprehend these abstract forms. It would be hard for them to visualize mentally the changes of values up and down the slopes and their rate of change along different gradients. Hence, much imagination and plenty of practice are required to perceive the volumetric distribution in a statistical map of this kind.

Areal patterns or colours are sometimes placed between isolines; the use of hypsometric tints in contour maps is a good example. Superficially, the tonal variation of the patterns helps the differentiation of values between the isopleths. Moreover, the map appears to be more graphic. However, the original smooth and undulating statistical surface will then be altered into a series of steps bounded by the isopleths. This is due to the uniformity of tones of the individual areal patterns which gives one an impression that it represents a flat surface. Therefore, this is not an ideal cartographic technique to be applied to isopleth maps.

Special Design Problems

Location of Control Points

This is a very important consideration in the construction of the isopleth map. The location of these points guides the orientation of the isopleths and hence determines the accuracy of the graphic representation.

In reality, the derived values such as population density never exist as points, simply because they are not obtained from actual

measurements at the locations where the points are to be established; instead a certain areal extent is involved in the computation of the data. To display population density by means of isopleths, a control point must be chosen as a representation of the value obtained from every administrative division. All these points will serve as bases for the plotting of the lines of equal value. The similarity of a control point in a statistical map and a spot height in a topographical map has been emphasized but their difference has been neglected. They both have a locational designation on the datum plane and represent an elevation value above it. There is no question about the similarity of their function. Regarding their dissimilarities, a control point never represents a negative value below the datum plane but a spot height sometimes does. The plotting of control points is subjective. It is solely determined by estimation. Contrarily, the placement of spot height is objective. They are located by scientific measurement on the land surface.

To locate the control points, due consideration must be given upon the shape of the statistical units and the nature of distribution of the phenomena within them. The geographical centre of an administrative division may not necessarily be the representative point unless the distribution pattern is uniform and the shape of the unit symmetrical. When the distribution is uneven and the shape of the unit irregular, the point will shift away from the geographical centre of the area. This point is "...the centre of gravity or pivot point where the distribution would balance as if it were supported by a rigid and weightless plane."[17]

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[17] J.R. Mackay, "Some Problems and Techniques in Isopleth Mapping," Econ. Geogr., Vol. 27, January, 1951, pp. 1-9.

It is not uncommon that the control point lies outside the statistical unit due to its peculiar shape. This is demonstrated by Mackay who shows how the representative point is established outside a bean shaped statistical unit and how it is further shifted towards the weight of concentration of the phenomenon.[18] In constructing an isopleth map, a carefully compiled dot map of the same area would be an useful aid. But still the production of an effective picture depends on the sound judgment of the cartographer.

Interpolation of Isopleths

This is a procedure which involves the placing of the isolines by referring to the values and the position of the control points already fixed on the base map. The number of these guiding points available will obviously be an important factor influencing the accuracy of the interpolation. When their numbers are few, there would easily develop situations of ambiguity. Under such circumstances, a reasonably precise or even correct placement of the isopleths would be in question.

Initially, all the control points determined previously are linked together by straight lines forming a triangular grid. When there is no supporting evidence showing the change of distribution along the interpolation axis, the intermediate values are usually assumed to be evenly distributed. In such instances, the points through which isopleths will pass will be placed at regular intervals along the axis. This linear interpolation shows that the values change at an even gradient between any two control points.

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18 Loc. cit.

When plotting the isopleths, if the distributional pattern of the phenomenon is followed closely, the resulting picture should disclose a more realistic situation. The spacing between the isopleths will seldom be at uniform intervals and the slopes will be concave, or even convex, depending on the nature of distribution of the phenomenon. If this technique is to be employed, reference to a dot map would help a more realistic placement of the line symbol. Besides, the use of the dot map helps to eliminate the ambiguity which the cartographer may come across during the interpolation. Although mathematical techniques have been introduced to deal with these particular situations, the resulting picture may be different from the real one.

An isopleth map should be compiled from a base map with statistical units having a regular shape and constant dimensions. When unequal or non-congruent base areas are used in constructing isopleths, the resulting map cannot be interpreted precisely nor considered statistically measureable.[19] The technical difficulty is obvious if one has to place an isopleth across an axis which joins two control points estimated from two administrative units of different size. The values can hardly be defined accurately along such an axis.

Two techniques have been introduced which eliminate the above two problems. A dot map is used in both cases. By the first method

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[19] Calvin F. Schmid and Earle H. MacCanell, "Basic Problems, Techniques, and Theory of Isopleth Mapping," American Statistical Association Journal, March, 1955, p.234.

a square grid drawn on transparent material is placed at any spot over the dot map. The control points and their values can be established by computing the dots appear at the coordinates of the grid.[20] Similar operation is repeated over the map until a sufficient number of control points have been obtained from which the isopleths are then plotted. This is a method by which the control points are established without referring to arbitrary determined statistical boundary. The resultant map will be far more accordant to the characteristic of the distribution of population than those compiled by the conventional method. Byron[21] has developed a densitometer, an electronic device used to measure density from dot maps. A carefully compiled dot map is placed under the scanning beam of the densitometer. The photocell of the device will record the amount of light intercepted by the black dots; the intensity will vary with the arrangement of the symbol over the map. The impulses received will then be transmitted to a uniformly calibrated meter from which the density readings can be obtained. From these results an isopleth map can be constructed. By means of this method, population density is measured without reference to any political boundaries. There will be no ambiguity arising from the use of conventionally determined control points for plotting isopleths.

Determination of Isopleth Intervals

In terms of importance, the choice of isopleth interval is analogous to the selection of class intervals in choroplethic mapping.

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[20] Ibid., pp. 238-239 (Map p. 237).

[21] William G. Byron, op.cit., pp. 41-48.

This is the very step by which the cartographer has complete control upon the appearance of the isopleth map.

One of the important factors is the map scale and the size of the format, assuming the same area is to be mapped. A map of small size drawn at small scale is unable to accommodate a large number of lines and thus only a few intervals representing the characteristics of the distributional pattern should be selected. Since more detail can be included in maps of large size with a large scale, the cartographer will have more freedom in choosing a finer interval. Consideration should be taken in regard to the number of control points on the base map. If only a meagre number is available, the choice of a small isoplethic interval would supply a wrong impression of the apparent accuracy of the map.

A close examination and careful analysis of the values of the control point will help to reveal the nature of the statistical data. This, in turn, will help the choice of a method to determine the intervals. Frequently, the drastic changes in population data do not favour the use of arithmetic progression to designate isopleth intervals. Though it shows a regular rate of increase which helps the comprehension and comparison of the various forms on the statistical surface, a large number of lines have to be used to encompass the whole range of data. This would produce superfluous detail. Another alternative would be the use of larger intervals, however, many significant variations will be hidden.

Regular intervals of two different sizes can help to overcome the above drawbacks. This technique is particularly suitable for the extremes that exist in population density. In urban centres, the over-

crowding of isopleths can be avoided if a larger interval is used. A small interval will amplify the low density values in the rural areas which would otherwise be obscured.

The geometric progression is favourable for rapidly increased values; for it does not change at regular intervals but increases by a constant ratio. The magnitude of increase at each step is governed by the ratio chosen. The unequal intervals will cause considerable difficulty in visualizing the undulating configurations on the statistical surface. A change of slope or gradient can hardly be conceived by the amount of spacing between the isopleths and the interpretation of the map will consequently be hindered.

Apparently, not all methods can be aptly applied to every set of data, for the nature of the latter is so varied. For a certain set of data, an arithmetic interval may give a better cartographic expression than a geometrical one. However, the testing of the data by graphs and sketch maps will, to a large extent, help the cartographer to make the best choice.

Plastic Shading on Isopleth Maps

Several techniques such as illuminated contours, relief shading and planimetrically correct terrain drawings[22] have been developed to assist the map readers to conceive the topographic forms

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[22] A.H. Robinson, op.cit., pp. 203, 206, and 211.

in relief maps. They do effectively change the two dimensional line patterns into a three dimensional surface which is intended to be shown by the contours.

Isopleth maps also delineate a surface having a vertical dimension. Such a surface is likewise difficult to comprehend except to an experienced user. The above techniques can be employed to achieve a three dimensional statistical surface on an isopleth map. It has been found that relief shading is comparatively simple and the result of the application to statistical maps is very effective. It consists essentially of patterns of light and shadow. They create an illusive effect of relief perception to the human eye. Psychologists discovered that in a picture if the shadow is below the centre of an object of any geometrical shape it will appear to us as a 'rise'. On the contrary, if the shadow is above the centre it will be seen as a 'depression'. This is explained by the fact that in our daily life, the sources of light, either natural or artificial, come from above. Thus the shadow of all the objects standing above the ground will be cast below their centre. Such repeated experience forms a psychological percept in our mind. This visual illusion is profitably utilized to improve the graphic quality of the map and to help the recognition of undulations on the statistical surface.

CHAPTER III

ANALYSIS OF SAMPLE MAPS

The maps that follow portray the population distribution and density in Census Division No. 11, Alberta. They are compiled from the 1961 Canada Population Census.

In preparing the illustrations no attempt is made to exhaust all the possible methods which can be used to portray these two aspects of population. Instead, emphasis is placed upon the study and analysis of the major considerations in the design of some map symbols and the application of cartographic methods used for these purposes.

Census Division No. 11 in Alberta (Fig. 1) has been chosen. The excessively large range in the number of inhabitants (5 persons in Township 45, Range 3, West of the 5th Meridian; 281,027 persons in Edmonton) present offers an excellent characteristic of population statistics. It is thus ideal for studying the various techniques employed to depict them, and lead to a better understanding of the problems.

The Geographical Setting of Census Division No. 11.

The Census Division 11, centrally located in the province of Alberta is roughly bisected into an eastern and a western half of the 114° longitude west. It has an area of 5530.5 square miles and a population of 410,679.[1]

Physiographically it lies on the highest of the three Prairie steps. The average elevation in the Division is 2,500 feet above sea level.

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[1] Canada Population Census, 1961.

The terrain over the area varies from flat lacustrine plain at the vicinity of Edmonton, gently rolling bevelled till plain over the eastern part of the Division, to undulating morainic knobs and depressions in the western part. The North Saskatchewan River, one of the main waterways in Alberta, flows diagonally from the southwest to the northeast of the area. The tributaries joining the river from the south and southeast are Washout Creek, Bucklake Creek, Modeste Creek, Strawberry Creek, Conjuring Creek, Whitemud Creek and Blackmud Creek; those from the northwest are Tomahawk Creek, Sturgeon River and other small ones. The general surface is dotted with lakes and undrained depressions of various size. These depressions are formed by the uneven deposition of morainic materials. The long ones, occupied by Coal Lake and Battle Lake, are old spillway channels. Lake Wabamum, site of one of the Province's thermal power stations, is the largest waterbody in the area.

The Division has a continental climate, the summers are moderately warm, the winters cold and dry. It is stimulating for human settlement. The frost-free period is, on the average, one hundred days which is long enough for crops to mature. The average annual precipitation varies from 16 to 18 inches and there is no pronounced deficit for crop growth.

The native vegetation cover is of the parkland type, which is a transition between prairie and aspen associations. Changes had taken place due to periodic burning and clearing for farming. At present the vegetative cover is dominantly grassland dotted with groves of aspen poplar at drier sites and balsam in wetter areas.

The soil over most of the area east of the 5th meridian (114°W)

is chernozemic which is developed from the grassland cover. The soil becomes solonetzic where the bedrock is close to the surface. Over the western half of the Division, the soil is mainly grey wooded due to the common occurrence of moss bogs and a denser mixed deciduous and evergreen vegetative cover. Such differences are reflected by the distribution patterns of the rural population which has a dominant agrarian economy. In the extremely fertile black soil area of the eastern half of the Division, the population is evenly and densely distributed, while over the western half large population voids are common and the people, on the whole, are thinly scattered because of the less fertile soil and the extensive boggy areas.

Edmonton, the provincial capital of Alberta, is the largest urban centre in the Division and is also a route focus, commercial and industrial city. It was established in 1805 at the present site as an outpost for fur traders and explorers because at that time the North Saskatchewan River was the main thoroughfare leading to the trading posts around Hudson's Bay. Settlements in the vicinity were accelerated by the completion of the railway connecting the city with Calgary in 1892 and an influx of immigrants from Central Europe about that period. Further expansion in economy was brought about by coal mining in the first quarter of the century and the discovery of gas in 1920. The discovery in 1947 of the oilfield at Leduc, about 14 miles south of Edmonton, triggered off an intensive exploitation of the mineral fuel and since then other productive activities resulted. These activities initiated a rapid industrial development and growth in the Edmonton area.

Most of the other nucleated settlements in the region are located near oil fields or along transportation routes, the latter serve as collecting centres of farm products in the area, so that there is within the Division today a number of sub-divisions which may be differentiated as urban or rural. It is with the mapping of these patterns of population distribution and density that this thesis deals.

The base maps are duplicated from the map of the Province of Alberta, Canada, on a scale of one inch to 12 miles compiled in 1962 by the Survey Branch Department of Highways, Alberta. The Census Metropolitan areas have been drawn according to the reference maps in Canada Population Census, 1961. All the maps had been reduced photographically to a convenient size (scale: one inch to 15 miles). A consistent map scale is used in all the sample maps of the study to ensure an easy comparison of the size of map symbols and the effects they created.

A general map (Fig. 2) has been prepared to aid the orientation of census tracts and important population centres of the Division. Physical data such as lakes, the North Saskatchewan River and its tributaries are also inserted. The inclusion of all this information in other maps would lead to unnecessary congestion and diminish the clarity of the illustrations. Hence it is more desirable to put these cultural and physical data on a separate map. In this study, it serves as a reference map from which one is able to understand the location of the map symbols in other sample maps.

Sample Maps Presented by Absolute Method for Showing Population Distribution

Figure 3 shows a geographical array of the original data. The number of the population has been transferred to each township and corporate areas on the map from the tabulated figures of the Canada Population Census, 1961. For accuracy, the array is unsurpassed by any other known cartographic methods. Its construction involves only simple transference of numbers and no further effort is required. However, representation of this type reveals no easily discernible patterns from which the map reader can establish relationships or make critical comparison of the phenomenon. Furthermore, it is non-pictorial and presents no aesthetic appeal.

Several examples of dot map and maps with dots and cartodiagrams have been made. The symbols include dots, proportional circles, cubes and spheres. When placing the dots on the maps reference was made to the following materials:

1. Topographic maps, scale: 1:50,000, produced by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, 1960 from air photographs taken in 1948 and 1957.
2. Topographic maps, scale 1 inch = 4 miles compiled in 1959 from aerial photographs. Drawn by the Forest Surveys Branch.
3. Air photographs, scale: 1 inch to 1,500 feet, taken in 1961.

The problem of dot placement became more and more difficult with the increase of the number of people represented by each dot. Some subjective judgment was needed in the process. In all cases the dots were inserted near to the centre of gravity of the population while consideration was also given to the distribution pattern of population in all the neighbouring areas.

Other diagrams were placed at the geographical centre of the settlements and thus present no special problem.

The preparation of the array is a necessary step when the map maker translates the bare statistics into cartographic symbols. As can be observed in this study, it is the basis from which a variety of population maps are constructed.

Figures 4 and 5 illustrate the inherent problem in the choice of dot size and dot value. For discussion purpose the symbols in both maps delineate only the scattered rural population. In Fig. 4 each dot represents 100 persons and the dot diameter is 0.013 inch.[2] Consequently, the dots are widely scattered and can be counted easily. Therefore estimation of the number of people in any locality is possible. However, their appearance conveys to the eye an immediate impression of 'emptiness' and thus shows no significant pattern of the population distribution in the Census Division.

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[2] A.H. Robinson, Elements of Cartography, John Wiley and Sons, Inc., 1960, p.160 (Table 9.1).

Fig. 5 gives a completely different picture. The dot diameter is increased to 0.035 inch but the number of people represented by each dot is reduced to 25. Naturally the reduction in value will require a larger number of dots. As a result, it supplies a detailed picture of the dispersed rural population. Owing to the large size of the symbol, the density of the dots is excessive. The overall impression created is deceptive. The rural population in this region appears to be very crowded. The fusing of dots around Edmonton and Jasper Place makes the estimation of the size of the population difficult although the actual number present is small. It can be seen from the two examples that two contrasting impressions can be achieved through the choice of dot size and value. The result can be misleading. A reasonable balance should be maintained between the dot size and the value it represents in order to ensure a correct impression of the distribution.

In Fig. 6 both urban and rural population in the Division are shown by uniform sized dots having a diameter of 0.013 inch. Each dot represents 25 persons. No coalescence of dots occurs at the rural areas. On the whole, it presents a reasonable detailed picture of the distribution pattern of the dispersed population. In areas where population concentrates, the dots merge together forming dark patches. The legibility of the individual dot became obscured. Because of the exceptional magnitude of population in urban units and the small value designated by each dot, a large number of dots results. At this map scale, the space available within the corporate boundary cannot possibly accommodate the large number of dots. In those congested areas, the map reader can hardly comprehend the magnitude of population present.

Figure 7. To show the dispersed rural population, similar dot size and value used in Fig. 6 have been retained since the result is satisfactory. Dots of larger size representing 100 persons each are designed to portray population at small towns and urban areas. The increased value of the dots has reduced the number appreciably. However, except at small population units (e.g. Calmar) where the dots can be discerned clearly, there is no improvement of the cluttered condition of the dots at larger urban conglomerations (e.g. Edmonton). It is evident that the change has only made a very slight improvement over the previous illustration.

The result demonstrates the usefulness of dots for portraying the distribution of rural population. They are by no means ideal for portraying population of urban character at the same scale. The limiting factors are the map scale and the magnitude of the population.

In terms of size and patterns of distribution, both urban and rural population possess a distinct characteristic of its own. To portray them on the same map, the use of diagrams in the form of proportional circles and dots would produce a satisfactory result. Also because of the difference in appearance of these symbols, the two basic components of population can be clearly differentiated. In Fig. 8, all urban population[3] are shown by proportional circles. Small conglomerations and

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[3] The difference of rural and urban for the 1961 Census was substantially the same as that used in 1956. Briefly, the 1961 definition specified that all cities, towns, and villages of 1,000 and over, whether incorporated or not, were classed as urban, as well as the urbanized fringes of (a) cities classed as metropolitan areas, (b) those classed as other major urban areas, and (c) certain smaller cities, if the city together with its urbanized fringe was 10,000 people or over. The remainder of the population was classed as rural. Introduction: Rural and Urban Distribution, published by Authority of the Hon. George Hus, Minister of Trade and Commerce, Dominion Bureau of Statistics.

scattered rural inhabitants are represented by dots. The advantage of this arrangement is apparent. All areas of coalesced dots as appeared in Fig. 6 and Fig. 7 are eliminated. The size of the circles is determined by the following method, shown in Appendix D. The formula πr^2 represents the population and the r calculated is then converted to inches by means of an engineering scale which has 60 equal divisions in each inch. If r is 320, the length plotted on the base line will be $\frac{320}{60}$ in. or 5 1/3 in. Perpendiculars are erected from the plotted points. An oblique line is then constructed through one end of the base line and intersects all the perpendiculars. The length of the perpendiculars from the horizontal base meeting the oblique line will be the radii of the circles. The size of the biggest circle, which should be adjusted to the size and the scale of the map, can be determined by adjusting the angle between the oblique line and the base. The size of the other circles will vary proportionally. As only the outlines of the circles are shown, they provide a comparatively weak visual impression. The significance of the symbols would be conceivably reduced.

Fig. 9 demonstrates another technique which can be employed with success to map population distribution. The population in the Division is made into several groups, each of which is represented by proportional circles, graduated symbols and dots. The open circles show the population in the four most populous centres. The size of the symbol is determined by the method used in Fig. 8, only that the angle is 8° instead of 10°. In this illustration because of the small number of the symbol and the obvious difference in their size, the exact number

of population in these four locations can be represented. From the map one can readily read off the number of people present in Edmonton or in Wetaskiwin. It has been found that when proportional circles are used to delineate small numbers of people, the size of the circles becomes more difficult to differentiate visually, hence it is equally difficult to compare or estimate the size of population they represent. To offset this drawback, two varieties of graduated symbols are employed to show population at small urban centres and rural agglomerations. For the former, larger shaded circles are used to show population ranging from 2,500 to 5,000 in number; smaller shaded circles depict smaller groups of inhabitants with their number ranging from 1,000 to 2,500. For the latter, groups of 500 to 1,000 people are shown by large solid squares and still smaller aggregates of 100 to 500 people by small solid ones. The sizes of these symbols visually, but not mathematically correspond to the quantities represented. In this particular case, mathematical accuracy does not offer any obvious advantages. Conversely, the number of people within a particular range can be identified easily at a glance. The scattered rural inhabitants, the last category, are represented by dots each denoting 25 persons.

Apparently, this technique has several merits: (1) it discloses the general characteristics of population distribution in the Division, (2) a wide range of quantity can be accommodated, and (3) all the dot clusters are avoided.

In Fig. 10 the size and value of all the graphic symbols in Fig. 9 have been retained but alternation has been made to those of

the dots. Larger-size dots each representing 50 people are used. One striking effect can be seen in this illustration. The dots offer a stronger visual impact than those in Fig. 9, and surprisingly, as a result, the open circles are seen to be more subdued. Therefore the comparision of Figures 9 and 10 shows clearly the influence of the 'cartographical environment' upon symbols. On the same illustration, physical data have been introduced. They are confined to lakes with considerable extent and the main river, the North Saskatchewan, which traverses the region. Addition of information of this nature to population maps has always been considered as one of the design problems. These non-population data tend to change the visual density of the tonal patterns in maps using the choroplethic technique or interrupt the line patterns in isopleth maps. In dot maps, the excessive use of these physical data would possibly destroy the overall pattern and impede the conveyance of essential information to the map reader. Yet, their presence in a limited amount, as shown in the illustration, surely shows better the location of the population. They may help to explain a particular pattern of distribution. For example, the presence of lakes on the map discloses the linear pattern of lake shore settlements.

Besides the two dimensional proportional circles, volumetric symbols have been frequently applied to mapping urban population distribution. Cubes and spheres are common examples. They possess the advantage of being able to deal with even larger magnitude and range of quantitative values than proportional circles. However, their weakness should not be ignored. When a symbol of this type is 10 times bigger

than another one, the quantity which the former represents will be 1,000 times larger than the latter. This amount of increase is usually not realized by the observers. Similar procedure as used in Figures 9 and 10 has been followed to find the radii of the spheres and the sides of the cubes, but the distance of the points from the zero of the base line vary with the cube roots of the number of people. In Fig. 11 the cubes are drawn isometrically to achieve three dimensionality. The effect is not destroyed although the symbols overlap in the vicinity of Edmonton. To assist the estimation of the number of persons they represent, a scale of value has been derived. The form of the cubic symbols is distinctly different from that of the dots and thus urban and rural populations can be clearly differentiated. One important defect of these cubic symbols can easily be recognized. They obscure all the dots which are present in the area. Thus the rural population distribution pattern adjacent to the urban areas is completely indecipherable. This problem can be alleviated by using only the outline of the cubes. But then the usual weakness of the symbol becomes the major drawback.

Graduated spheres are other three dimensional symbols commonly used in depicting urban population. They are constructed in two conventional forms: either as globes covered with graticules[4] or as balls in solid colour with a small illuminated area near the top.[5] Like cube

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[4] Guy Harold Smith, "The Population of Wisconsin," (Map opposite p. 420), Geog. Rev., Vol. 27, No. 3, July 1928, pp. 402-421.

[5] F.J. Monkhouse and H.R. Wilkinson, Maps and Diagrams, Map 3 p.278.

symbols, these spheres tend to obliterate the dots beneath them. In Fig. 12 plastic shading is applied to the symbols to simulate the three dimensional effect. Their exclusively aesthetic quality easily arouse visual attraction. The defect possessed by the conventional spheres has been considerably reduced. The dots can still be discernable in the shaded portion of the spherical symbols. For practical purposes and from the aesthetic point of view, the symbols in this sample map should be much preferable to other spheres used conventionally.

Sample Maps Presented by Relative Methods for Showing Population Density

Fig. 13 is a geographical array of the population density (see p. 31) in Census Division No. 11, Alberta. When the locational information of the statistics is to be sought, however, the array is much to be preferred to figures arranged in tabular form. Furthermore, it provides a more convenient basis from which a diversity of density maps can be prepared.

The following series of choropleth maps showing population density serve two main purposes: (1) they demonstrate the diverse impressions resulting from the different intervals chosen from the data, (2) they are the bases from which the validity of several techniques used in grouping the data can be assessed and analyzed. For these reasons the administrative boundaries are utilized as density unit limits. Otherwise, another method such as dasymetric technique, which would give a greater refinement of the density, should be employed.

For determining the density class intervals, different systems

of progression have been used. Fig. 14 illustrates an arithmetic progression in the order of 0 - 2 - 4 - 6 - 8. As the number of class is confined to eight, it only reaches the value of 16 at the top. On the map the highest class embraces all other higher values within the range but there is no way by which they can be shown. All the variations and significance towards the higher end of the scale are completely concealed. In fact, the density value of 14 is not present in the statistical data (see Appendix A).

This sample map gives to the observer an immediate impression of the low population density in most parts of the Division. If arithmetic progression has to be used, in order to encompass the whole range of statistics, every step has to increase by 800. A sequence of density classes is formed in the order of 0-799.9, 800-1,599.9, 1,600-2399.9, etc. When the original data are examined, only four density values among 196 are over 800. They are 1,776.7, 4,662.2, 5,109.6 and 6,000 (see Appendix A) which could be included in the third, sixth, seventh and eighth classes respectively. No value is represented in the second, fourth, and fifth classes. Obviously, arithmetic progression is far from satisfactory as a means for grouping population density. The result obtained from using this method only discloses a part of the picture, and such a picture can be an unrealistic one.

The geometric progression in Fig. 15 triples at each step (e.g. 0-2.9, 3-8.9, 9-26.9, 27-80.9). It is able to embrace the entire range of the statistical data without increasing the number of classes. There are no particular details accentuated at any part of the whole

scale. Below the density value of 25, adequate detail is shown, yet the higher density values are not neglected. However, the system is not entirely free from criticism. Only one value is represented in the sixth and the seventh classes, though they do not bear any special characteristic in the data.

In Fig. 16 the geometric progression increases in the following manner (e.g. 0-4.9, 5-24.9, 25-124.9, 125-624.9, 625-3,124.9, etc.). The method is able to cope with greater extremes of value because it reaches the maximum value much sooner. Here only six classes are required. The number is sufficiently small and the differentiation of the pattern symbols is much easier. These are the obvious advantages over the arithmetic progression. Yet, the 'breaking points' have no relationship with the nature of distribution of the statistics but are rather governed rigidly by the mathematical systems.

The density groups in Fig. 17 are divided by the modified Septile System. The whole range of statistics is ranged in an ascending order. All the repeated values in the series are excluded in order to avoid the recurrence of numbers in the groups as so often occurs. In addition, the last class will thus be able to include a comparatively narrower range of the data, usually including numbers separated by wide intervals. This would help to reduce the degree of generalization. The total number of non-recurring density values in Division No. 11 is 138 and is divided into six groups of twenty three units each. The limits of value in each group are determined by the nature of the statistics. If wide gaps exist in the statistical array, the range of values encom-

compassed by the group will naturally be larger (see Appendix B). The last group in the illustration demonstrates this effect. It includes figures from 30 to 6,000. The other five groups show a consistent increase of the value from the lowest denomination to 27.6. The resultant map shows good detail of density values for that range. Over generalization in the last class is evident. This constitutes the major drawback of the method. The map reveals the exact lowest and highest density values, but still it fails to show the complete picture.

The six classes in Fig. 18 are not derived from any mathematical process or statistical system, but their division is rather based on an analysis of the original data. Those density values below 10 form a dominant group in the illustration because they occupy 61.2 per cent of the total density values in the series. They surely represent a significant characteristic in the Division. Owing to the uneven distribution of the population data and the common occurrence of intervals in the statistical series, it is not necessary for the class limits to follow one another successively. Between the fourth and the fifth classes the whole range of values from 500 to 1,500 is omitted. These values are absent in the data and it is meaningless to include them in any of the groups. Instead, this gap can be used profitably as a 'breaking point' between two density groups. During the grouping, caution is also taken against excessive generalization within the density classes, which might hide the important intermediate values. The map would enable the observer to obtain an impression of the general character of the population density in the Division as well as the location of high density areas.

All too often, mathematical processes are used to determine intervals of isopleths in population density maps. The methods are simple, but the result, as in the case of choropleth maps, is far from satisfactory. As is evident from the previous examples, the nature of the data imposes limitations to their application.

In choosing isopleth intervals, the map maker usually has more freedom than selecting class intervals in choropleth maps. In the case of the isopleth map, the use of shaded patterns is not absolutely necessary, hence the restrictions involved are no longer present. Theoretically fine intervals can be chosen, but in practice, as in this particular case, the extreme wide range and the nature of the data make this undesirable. Nor is the map at the present scale able to accommodate the detail. In Fig. 19 the isopleth intervals have been chosen rationally in order to bring out the characteristics of the data. The choice is determined primarily by the distribution pattern of the density values in the statistical array. Upon examination, the data show a steady increase at the lower end of the scale but from 25.5 onwards, the values probably representing urban character, increase more and more irregularly and sporadically. Therefore, basically, the lower density values are shown at smaller intervals which reveal the tendency of gradual change in population density in rural areas. For higher values, wider intervals have been selected. These isopleths are found at urban centres or near to nodes of population concentration. In these areas the lines are closely spaced and the intermediate values between them cannot be comprehended. In fact many of them do not exist. This would rather help the reader to

realize the abrupt change of population density at urban areas. The steps of the isopleths are irregular, only those values which show a significant trend of the density are selected.

The statistical surface which theoretically exist in isopleth maps, as illustrated in Fig. 19 is not readily understood by the average map user. In appearance it is visually weaker than the dot maps or the choropleth maps. In common practice, layer tints or colours are applied between the isolines (chorisopleths)[6] to give a stronger visual appeal to maps of this type; but then the statistical surface is wrongly represented. It presents an erroneous impression that all the changes along the isopleths are abrupt, and all the distribution between them even. In population maps, there is a general tendency for the density changes in rural areas to be more gradual and those around urban areas abrupt. It is logical to apply plastic shading over the rural regions to bring out the characteristic gradual transition of the density. The effect showing sudden changes at the urban centres can also be obtained from the same technique. This is illustrated in the sample map (Fig. 20). The light and shadow simulate a three dimensional effect of the undulations. To accentuate the change in relief, the principle of 'the higher, the darker' has been followed. Thus the changes on the surface can be recognized readily.

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[6] J.K. Wright, "The Terminology of Certain Map Symbols," Geog. Rev., Vol. 34, October, 1944, p.655.

Figure 1

NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
MONTANA U.S.A.
FORT VERMILION
FORT McMURRAY
PEACE RIVER
GRANDE PRAIRIE
ATHABASCA
EDSON
LLOYDMINSTER
CAMROSE
WAINWRIGHT
RED DEER
HANNA
DRUMHELLER
BANFF
CALGARY
MEDICINE HAT
LETHBRIDGE
PINCHER CREEK
Peace River
North Saskatchewan
Red Deer River
South Saskatchewan River
15
12
13
14
11
10
7
8
9
4
5
6
3
2
1
ALBERTA
CENSUS DIVISIONS
1961
0 20 40 60 80 100 Miles
International Boundary
Provincial Boundary
Census Division Boundary
STUDY AREA
K. I. FUNG

Figure 2

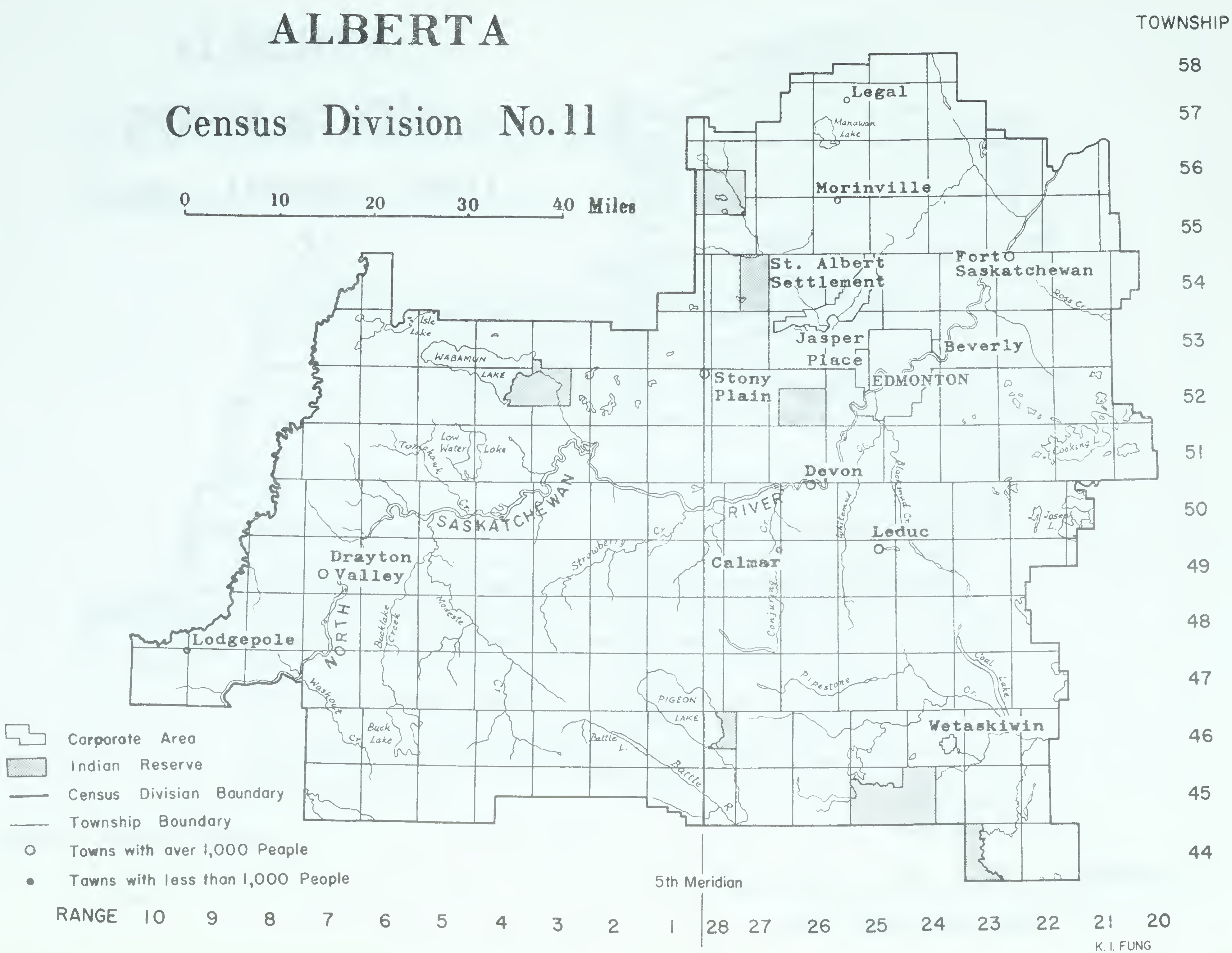
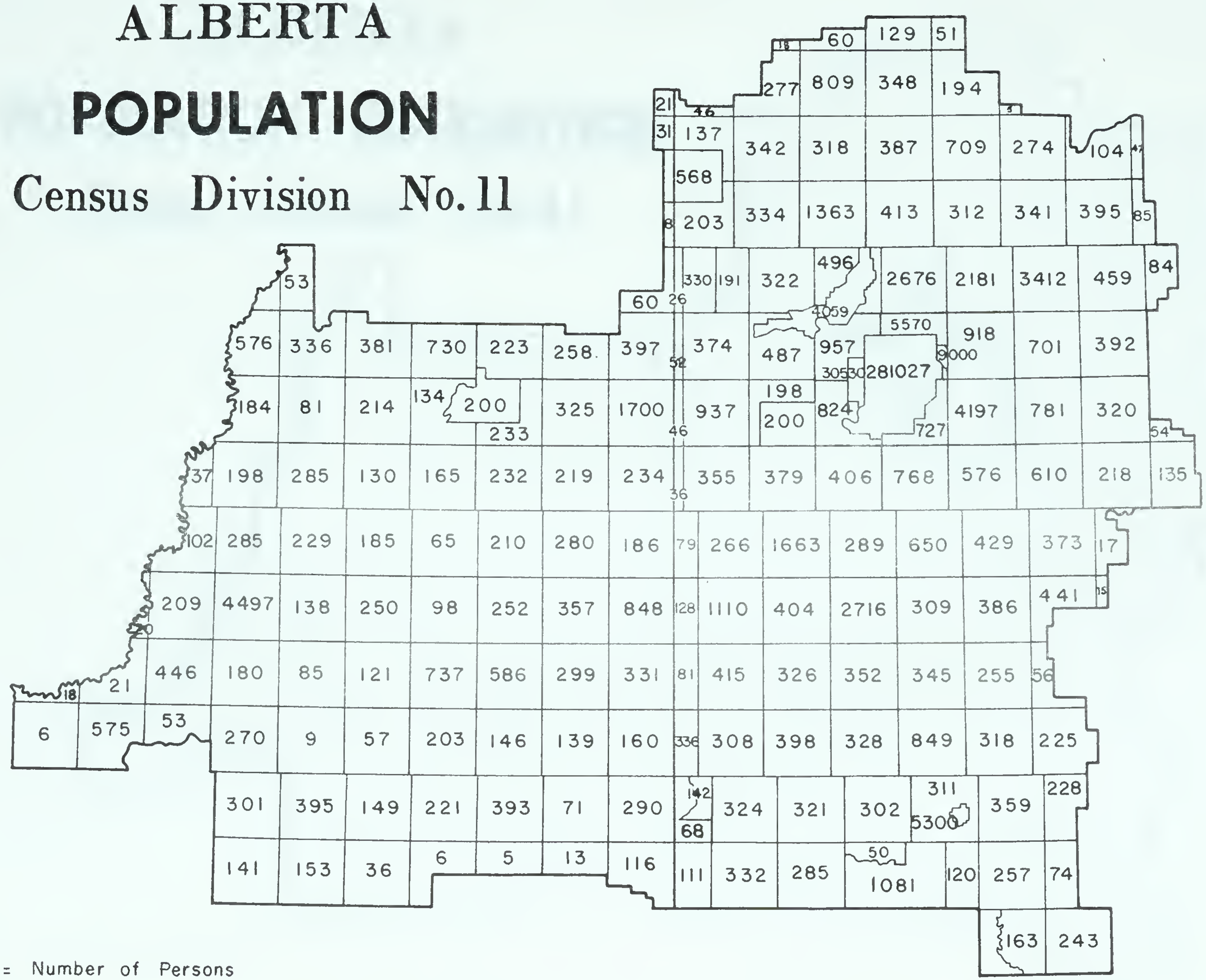

ALBERTA
Census Division No. 11
0 10 20 30 40 Miles
TOWNSHIP
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
Legal
Manawan Lake
Morinville
St. Albert Settlement
Fort Saskatchewan
Ross Cr.
Jasper Place
Beverly
EDMONTON
Stony Plain
Isle Lake
WABAMUN LAKE
Low Water Lake
Tomahawk
Cooking L.
Devon
Blackmud Cr.
Whitemud
SASKATCHEWAN
RIVER
NORTH
Joseph L.
Leduc
Calmar
Strawberry Cr.
Drayton Valley
Conjuring
Modeste
Bucklake Creek
Lodgepole
Washout Cr.
Coal Lake
Pipestone
PIGEON LAKE
Wetaskiwin
Buck Lake
Battle L.
Battle R.
Carporate Area
Indian Reserve
Census Division Baundary
Township Boundary
Towns with aver 1,000 Peaple
Tawns with less than 1,000 People
5th Meridian
RANGE 10 9 8 7 6 5 4 3 2 1 28 27 26 25 24 23 22 21 20
K. I. FUNG

Figure 3

ALBERTA
POPULATION
Census Division No. 11



Numerals = Number of Persons

K. I. FUNG

0 10 20 30 40 Miles

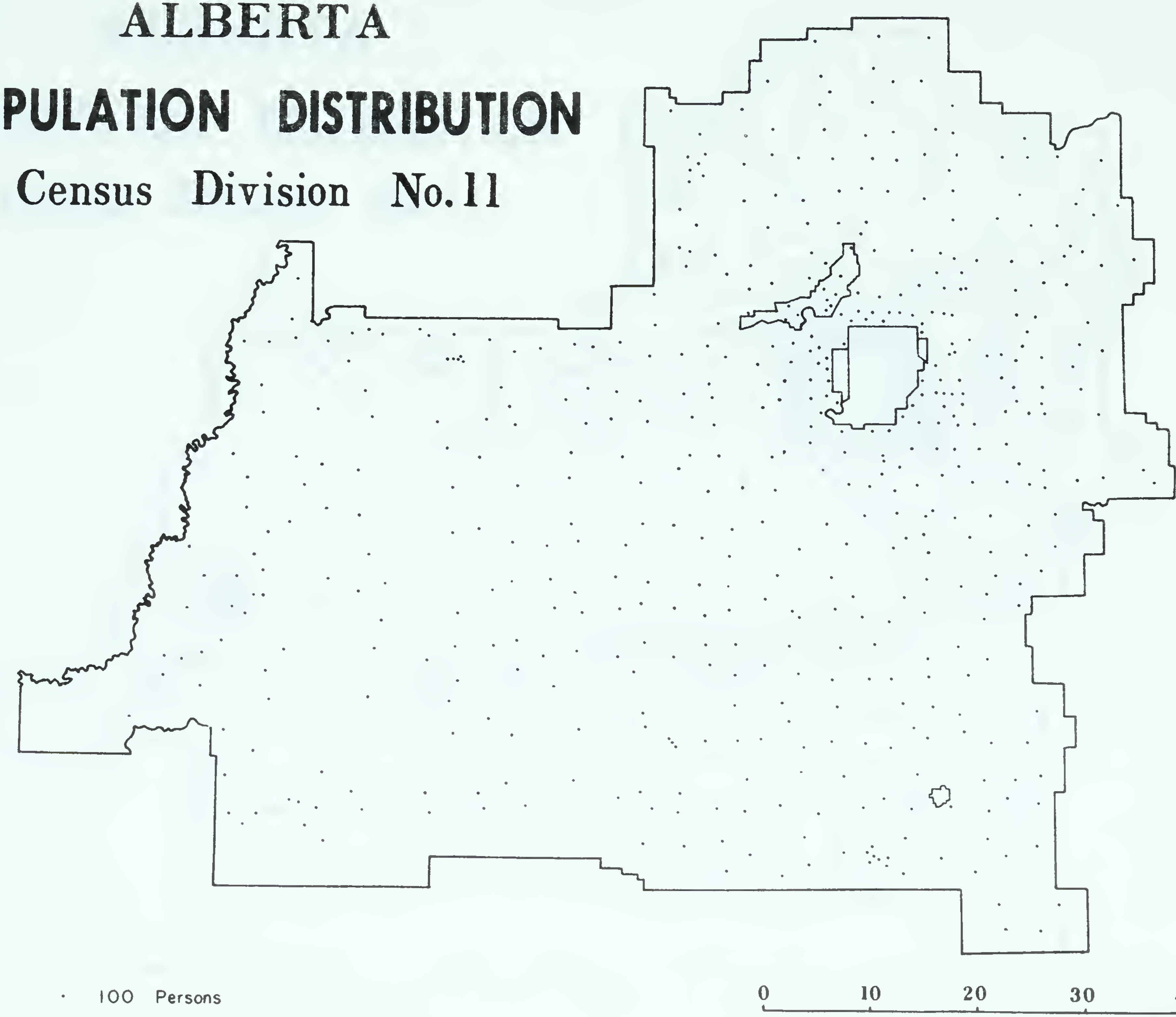
Source: Canada Census, 1961

Figure 4

ALBERTA

POPULATION DISTRIBUTION

Census Division No. 11



Source: Canada Census, 1961

K I FUNG

Figure 5

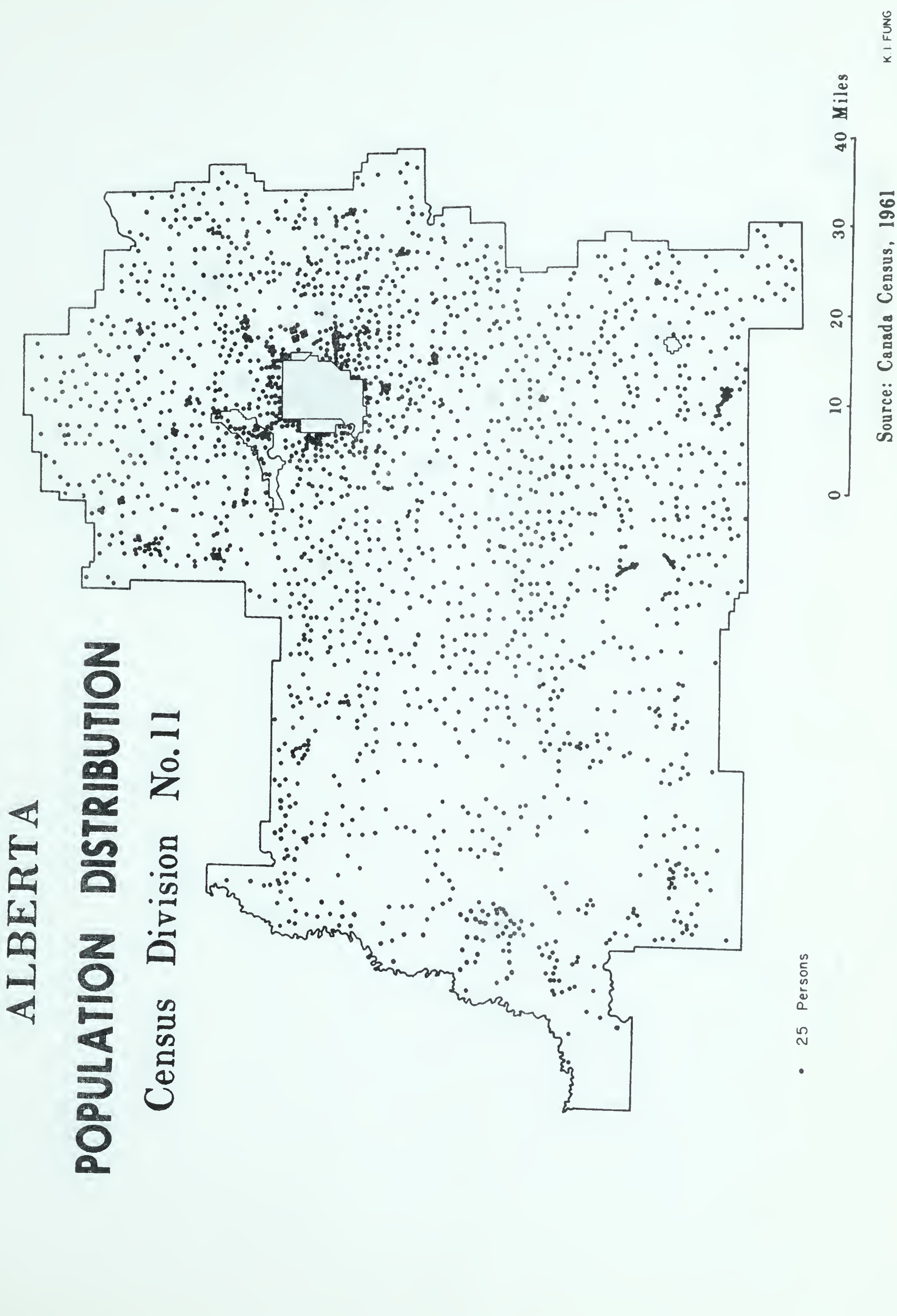
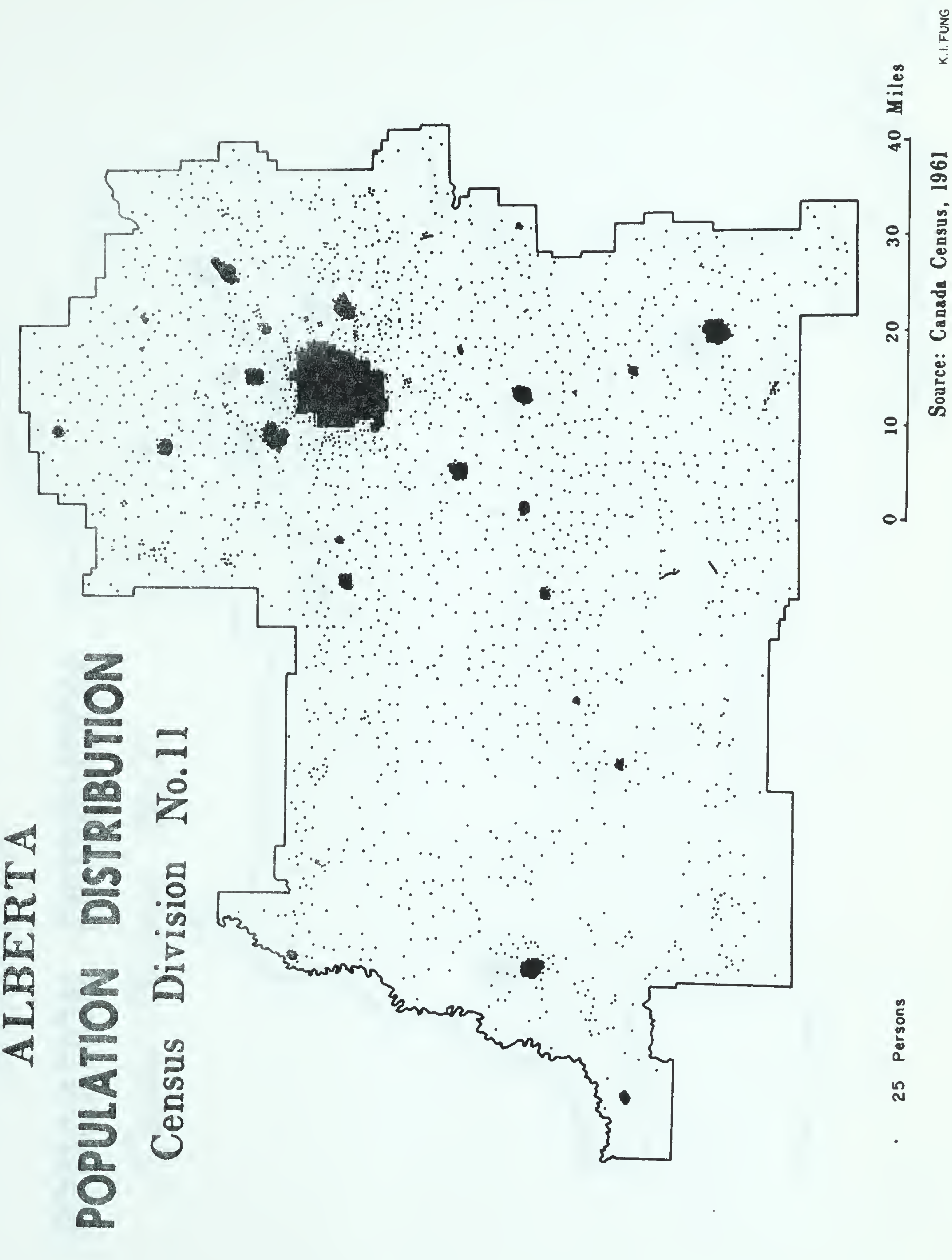

ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11
• 25 Persons
0 10 20 30 40 Miles
Source: Canada Census, 1961
K I FUNG

Figure 6



ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11
· 25 Persons
0 10 20 30 40 Miles
Source: Canada Census, 1961
K.I. FUNG

ALBERTA

POPULATION DISTRIBUTION

Census Division No. 11

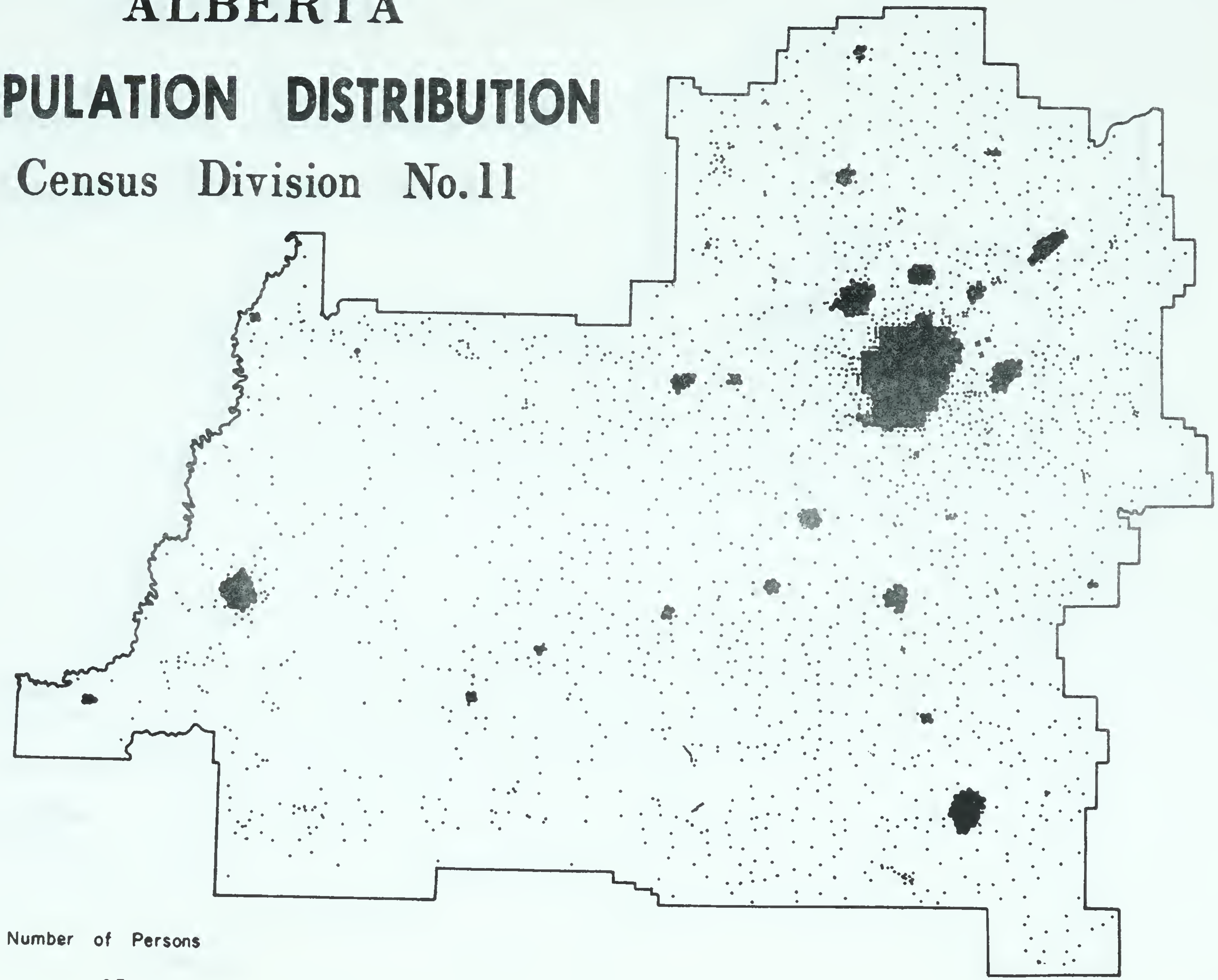
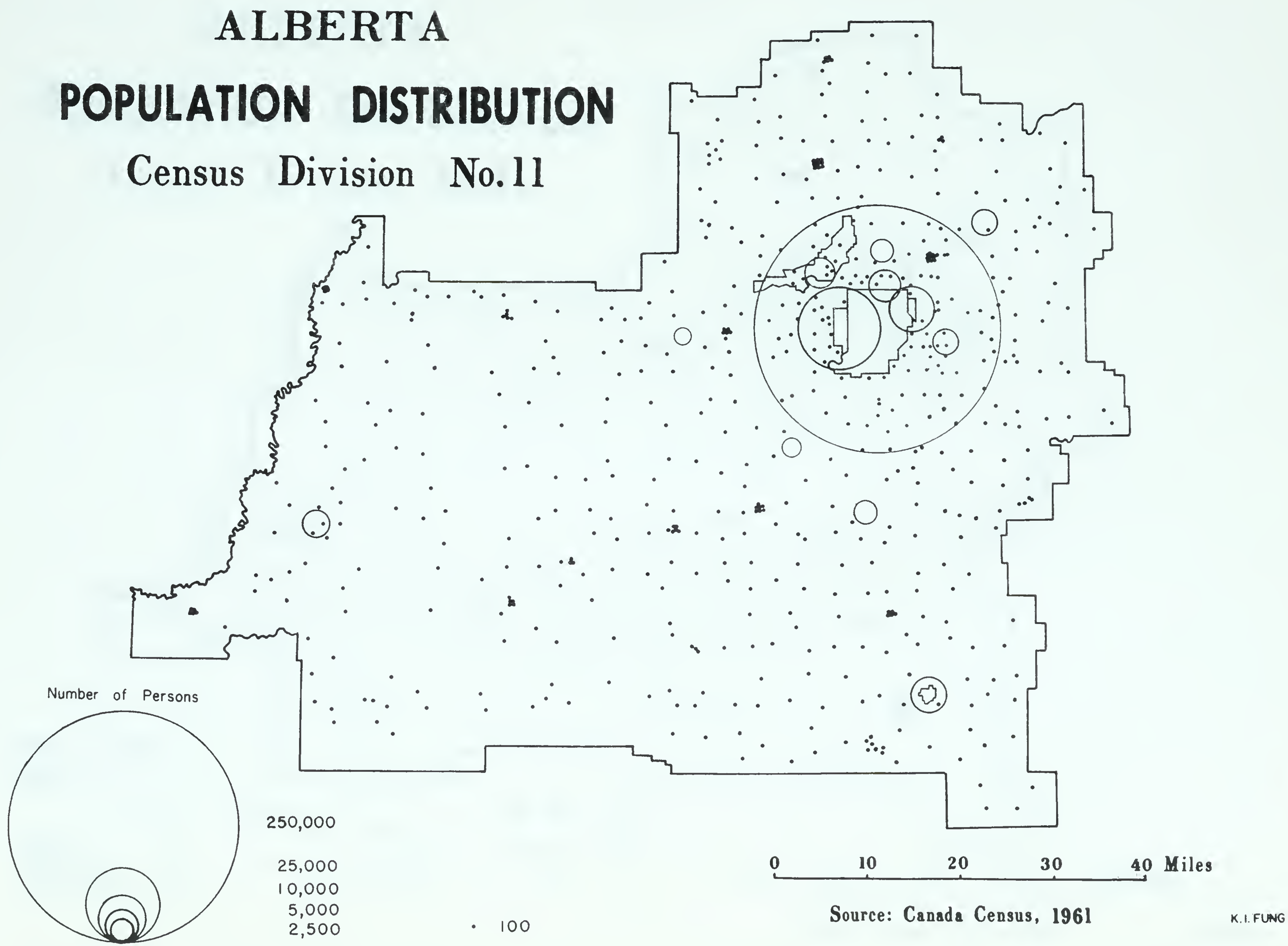
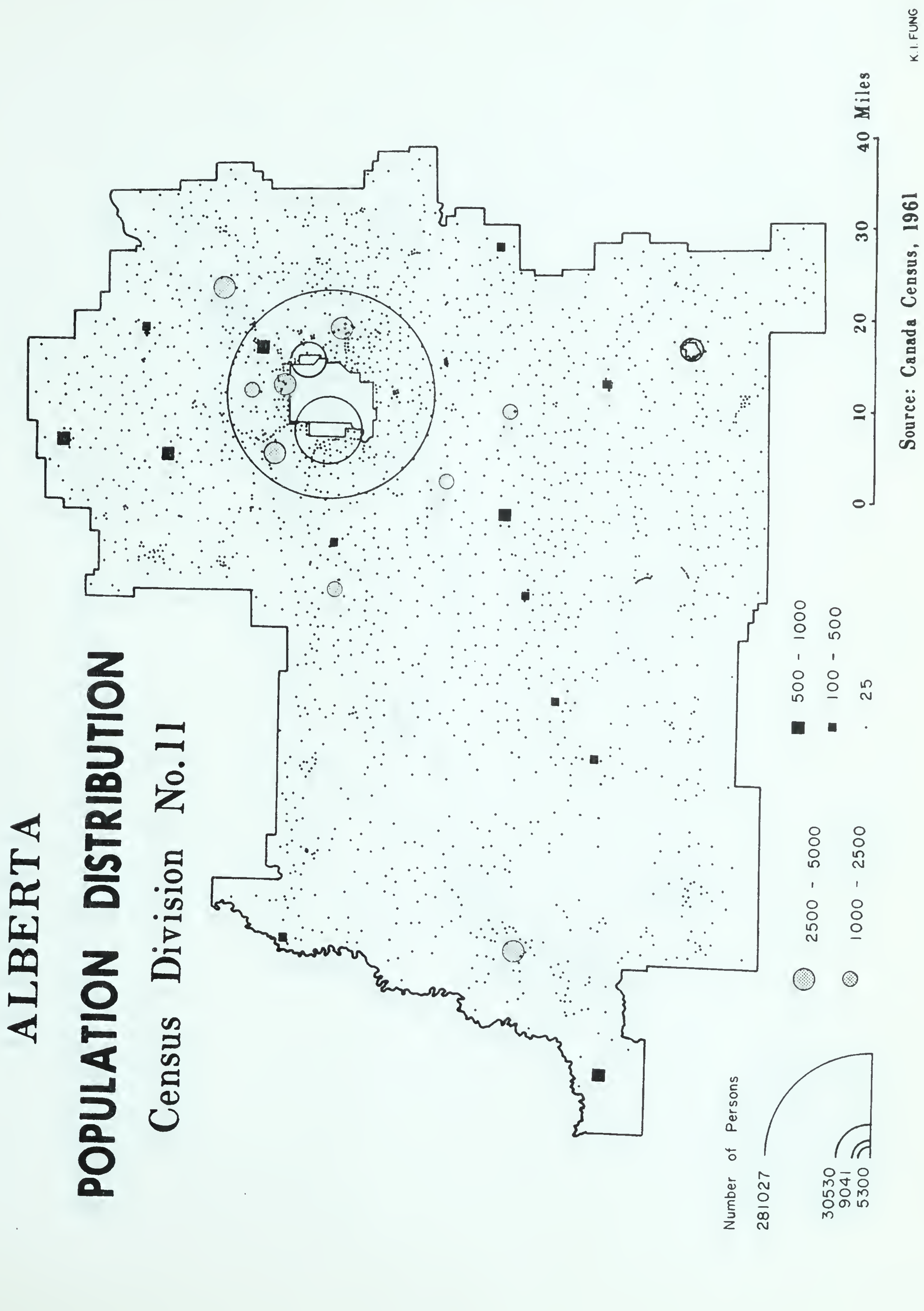


Figure 7



Source: Canada Census, 1961

Figure 9



ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11
Number of Persons
281027
30530
9041
5300
2500 - 5000
1000 - 2500
500 - 1000
100 - 500
25
0
10
20
30
40 Miles
Source: Canada Census, 1961
K.I. FUNG

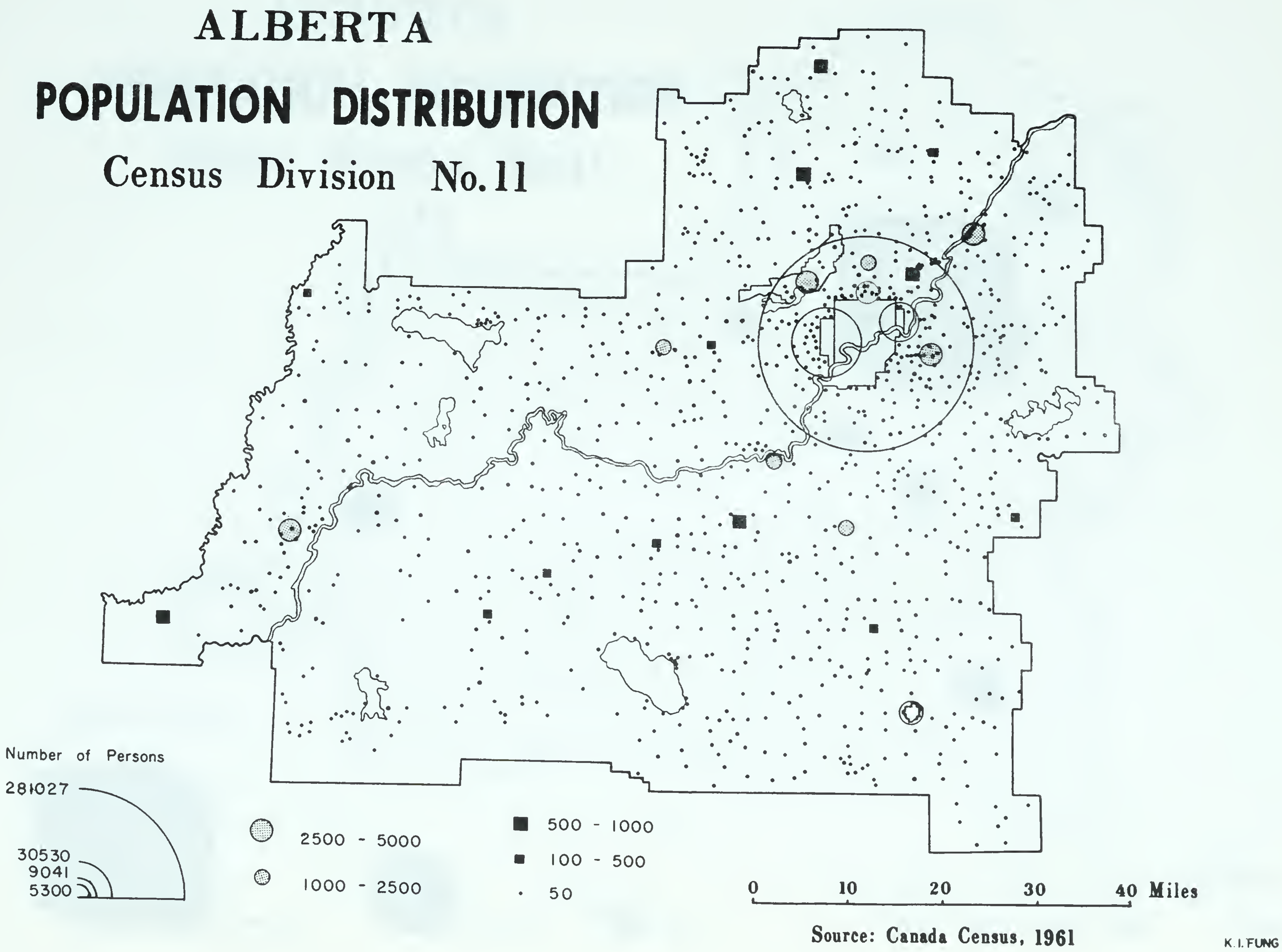

ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11
Number of Persons
281027
30530
9041
5300
2500 - 5000
1000 - 2500
500 - 1000
100 - 500
50
0 10 20 30 40 Miles
Source: Canada Census, 1961
K. I. FUNG

Figure 10

POPULATION DISTRIBUTION

Figure 11

ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11

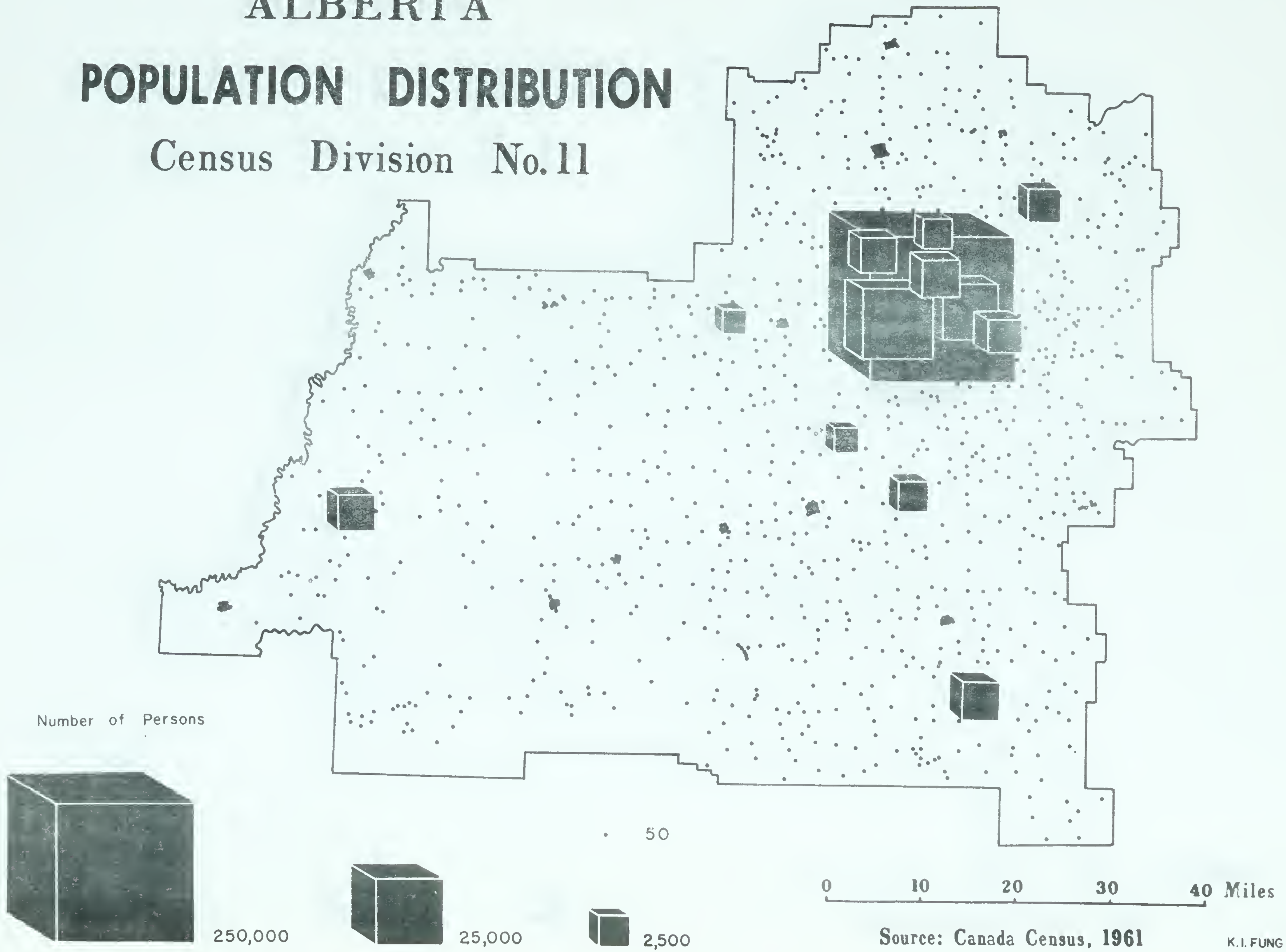
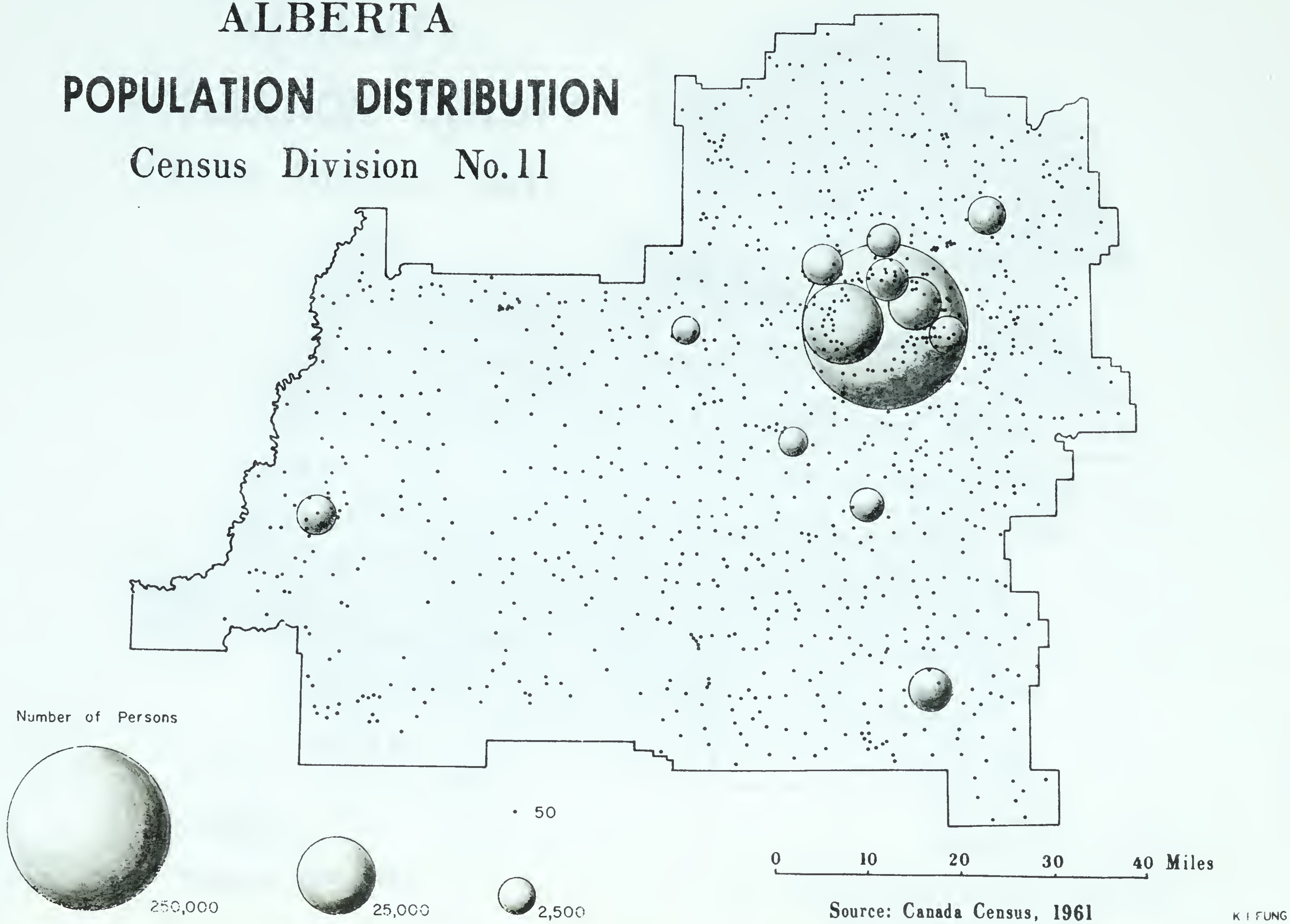


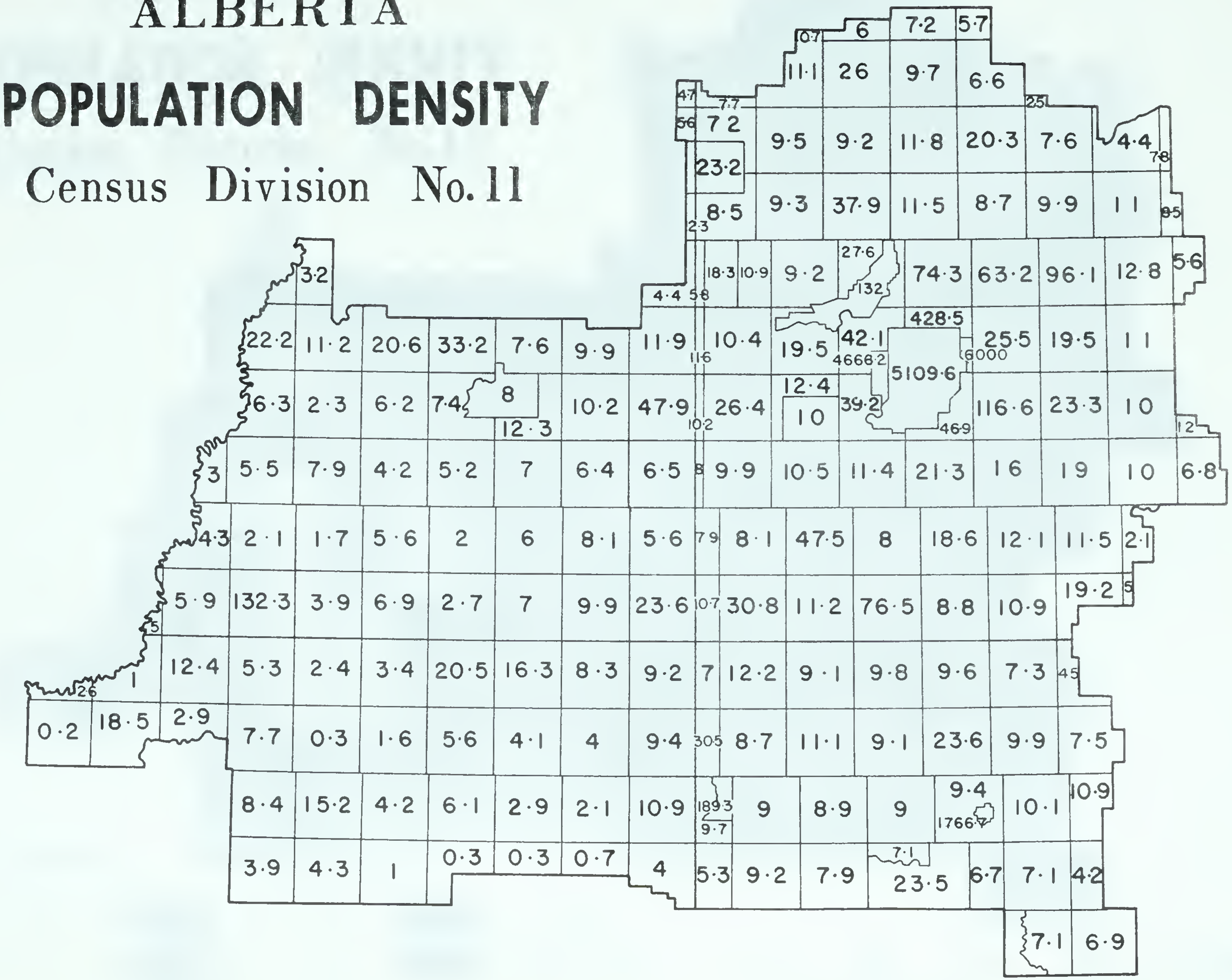
Figure 12

ALBERTA
POPULATION DISTRIBUTION
Census Division No. 11



Source: Canada Census, 1961

ALBERTA
POPULATION DENSITY
Census Division No. 11



Numerals = Number of Persons per Square Mile

0 10 20 30 40 Miles

Source: Canada Census, 1961

K. I. FUNG

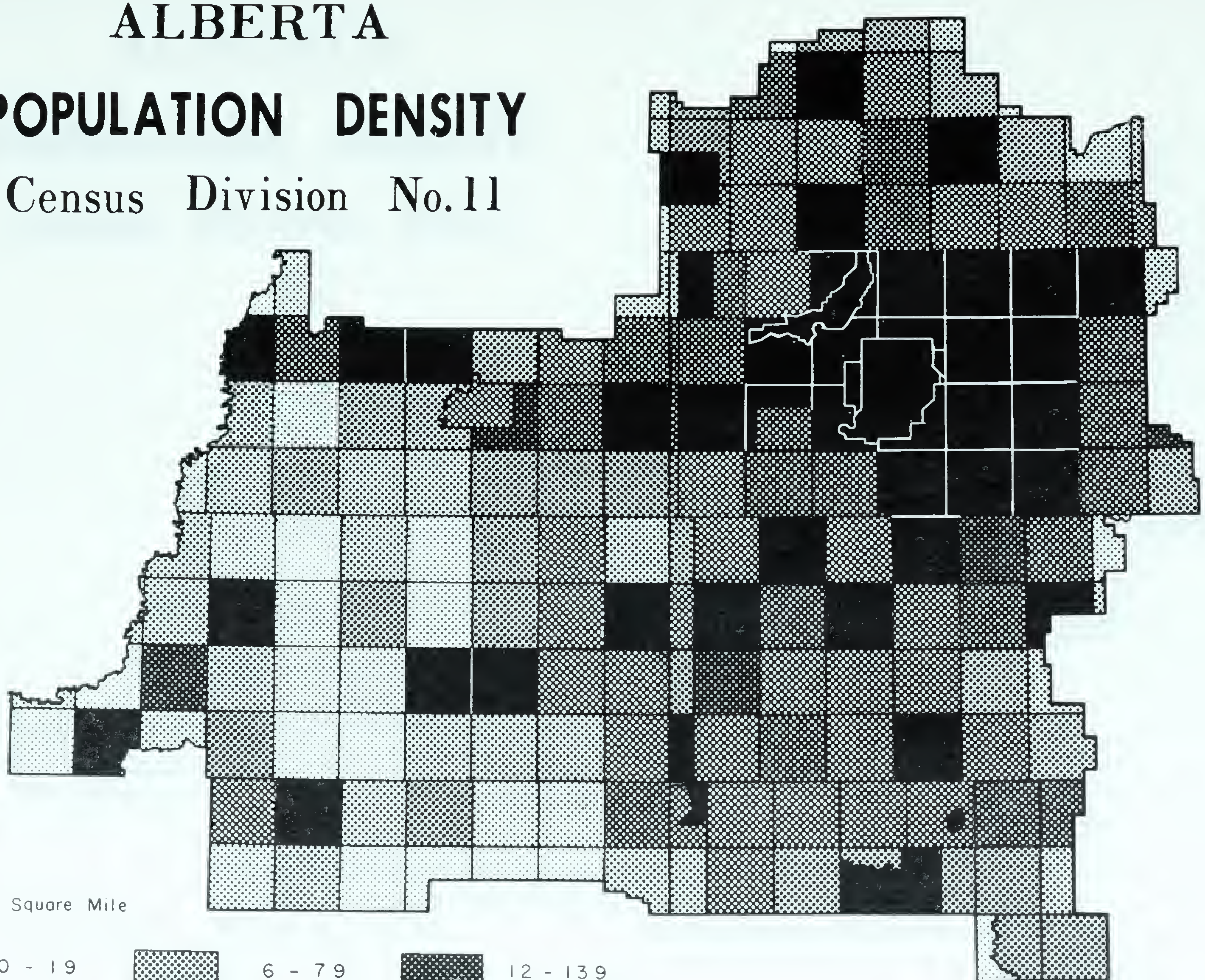
Figure 13

Figure 14

ALBERTA

POPULATION DENSITY

Census Division No.11



Persons per Square Mile

0 - 1.9
2 - 3.9
4 - 5.9
6 - 7.9
8 - 9.9
10 - 11.9
12 - 13.9
14 and Over

0 10 20 30 40 Miles

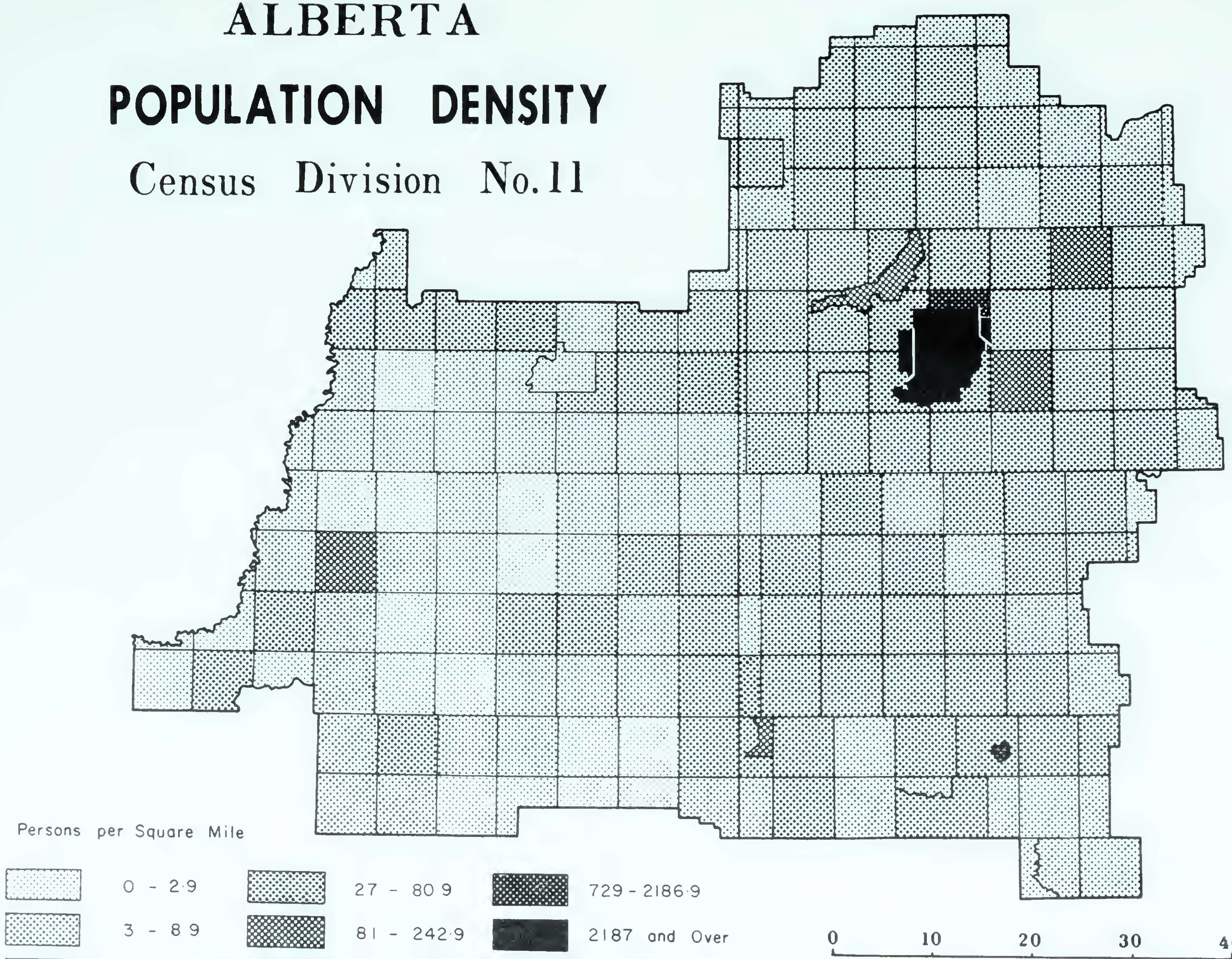
Source: Canada Census, 1961

K I FUNG

ALBERTA

POPULATION DENSITY

Census Division No. 11



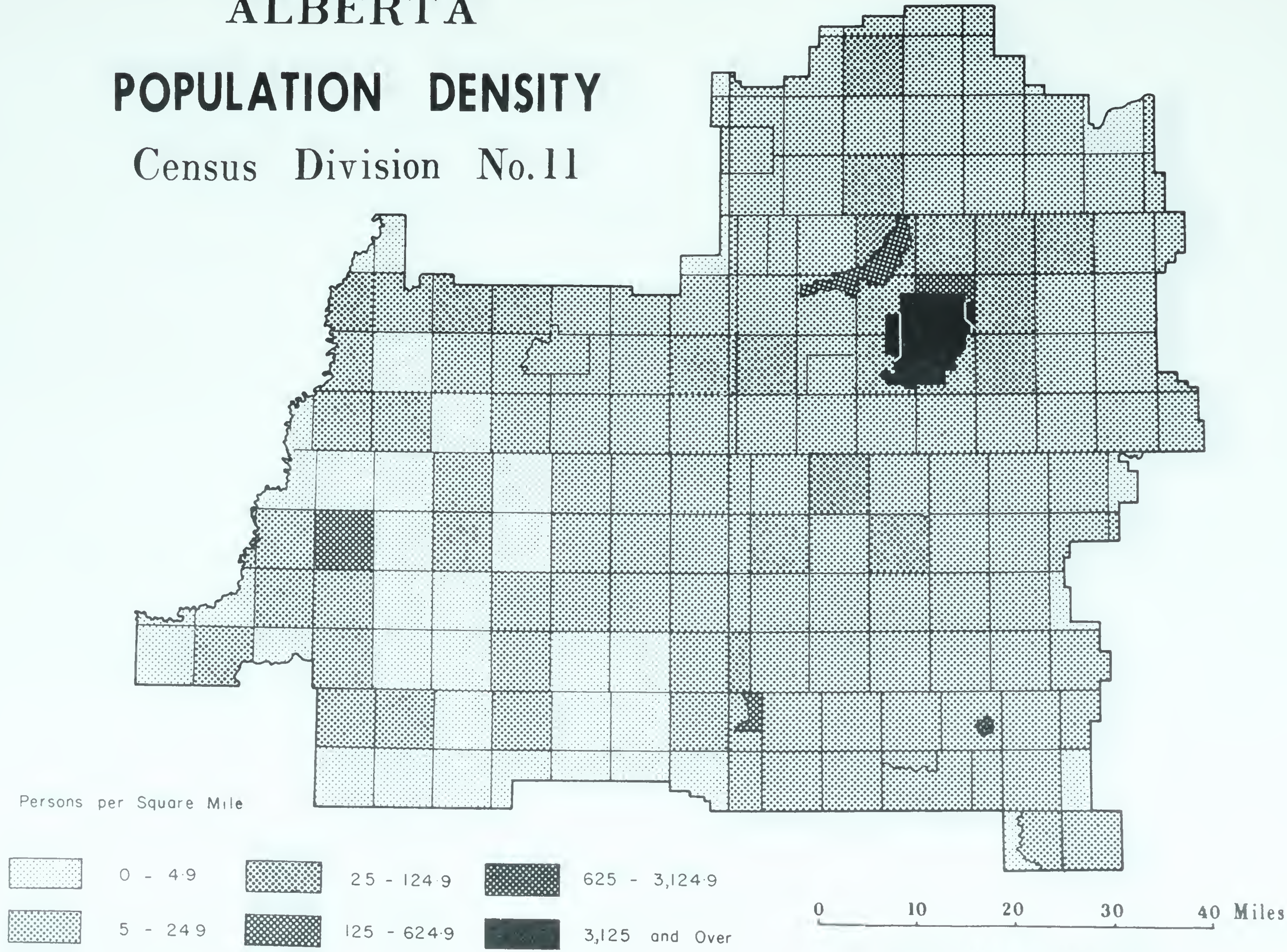
Source: Canada Census, 1961

K I FUNG

ALBERTA

POPULATION DENSITY

Census Division No. 11

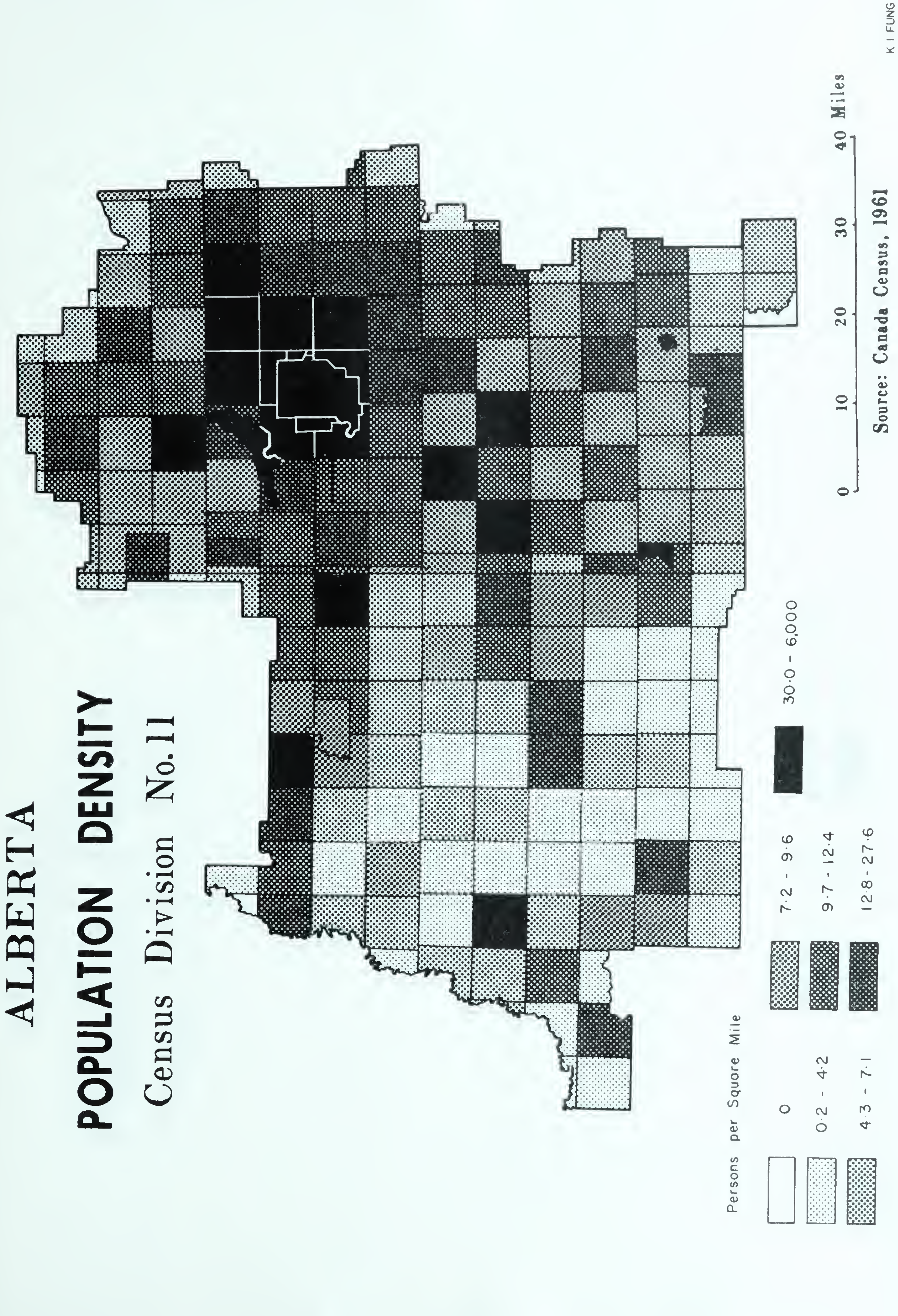


Source: Canada Census, 1961

K I FUNG

Figure 16

Figure 17



ALBERTA
POPULATION DENSITY
Census Division No. 11
Persons per Square Mile
0
0·2 - 4·2
4·3 - 7·1
7·2 - 9·6
9·7 - 12·4
12·8 - 27·6
30·0 - 6,000
0
10
20
30
40 Miles
Source: Canada Census, 1961
K I FUNG

ALBERTA

POPULATION DENSITY

Census Division No. 11

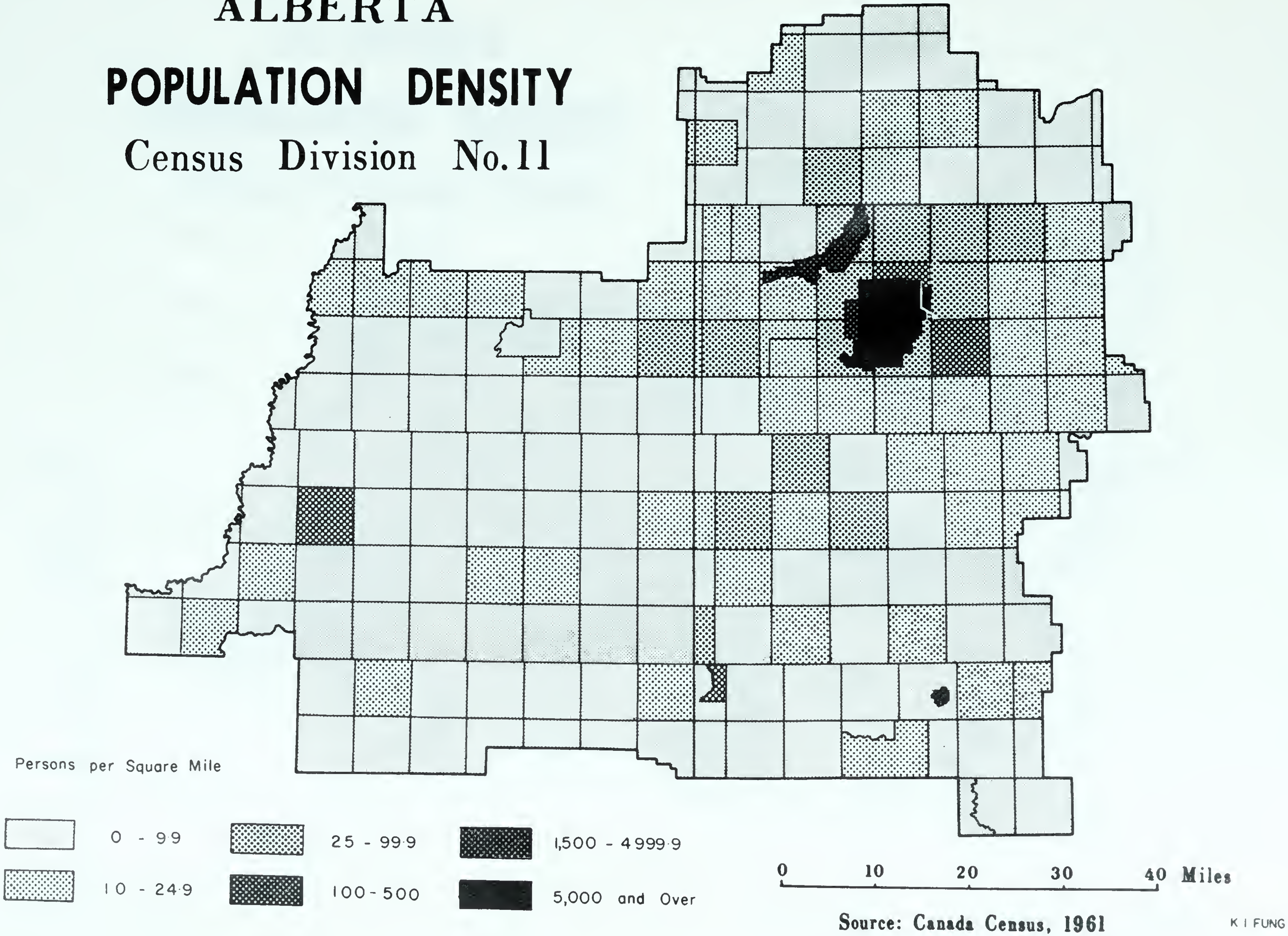
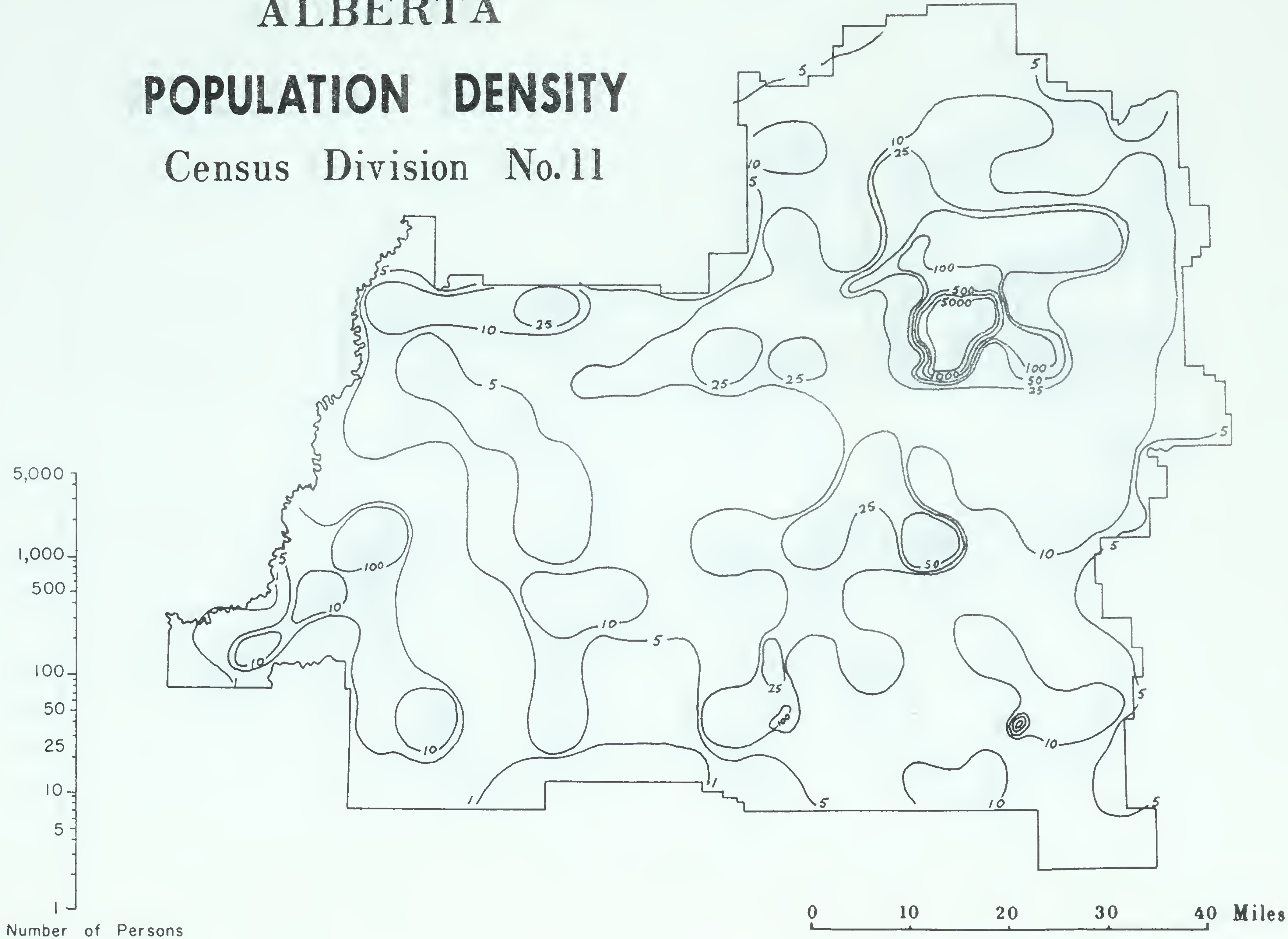


Figure 18

ALBERTA

POPULATION DENSITY

Census Division No. 11



Source: Canada Census, 1961

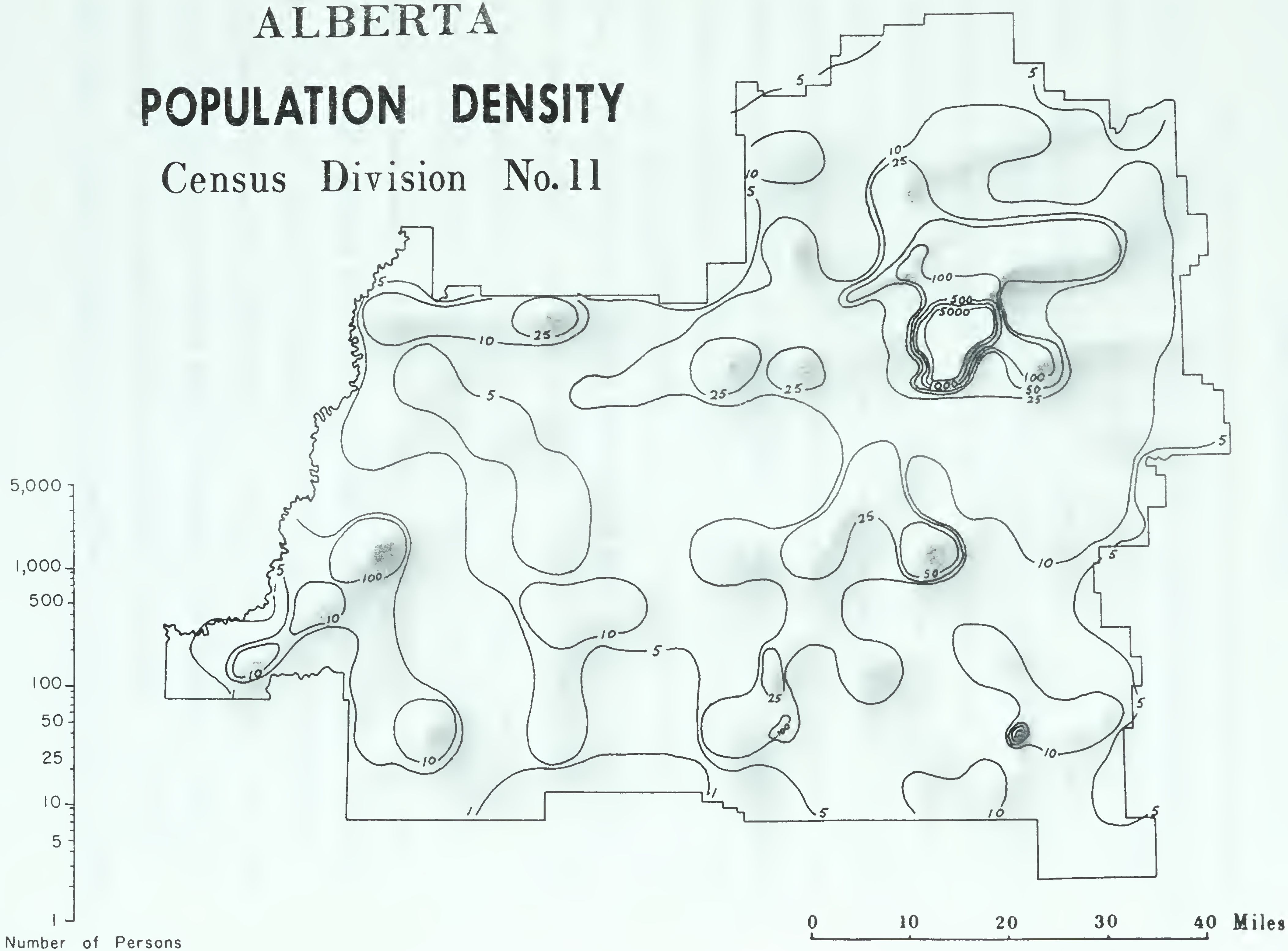
K.I FUNG

Figure 19

ALBERTA

POPULATION DENSITY

Census Division No. 11



Source: Canada Census, 1961

K I FUNG

CHAPTER IV

SUMMARY AND CONCLUSION

The first consideration in constructing maps depicting population distribution and density should be the thorough understanding of the basic problems involved. The original data could be distorted through the poor choice of a map projection. The map scale is also an essential cartographic element as it controls the choice of size and value of dots and diagrams, and the degree of refinement in the selection of density intervals in choropleth and isopleth maps. In order to present a true picture, the detail of the information to be presented has to be in harmony with the map scale. A good knowledge of the basic design and the inherent visual properties of map symbols lead to a better understanding of their suitability for portraying distribution and/or density of population. All map symbols should be simple in form and effective in function. Optical illusion in map reading is a human factor that varies with the individual, and this still remains an unsolved problem though it can be ameliorated by careful choice and handling of technique. Serious consideration of this problem should be an integral part in population map design. Since the size of point symbols and the intensity of areal symbols are the direct means of representation of different relative values, the usefulness of the map will be considerably degraded if either the symbol size or the pattern intensity is not seen as it is. Special attention should be paid to the design of form and arrangement of the symbols, which may induce this defect. Although the effect created by plastic shading applied to isopleth maps and spheres

is an optical illusion, this technique helps the map reader to visualize the third dimension on a two dimensional medium. A general knowledge of the geographical factors governing the distributional pattern of population will help the map compiler to place the graphic symbols at appropriate locations over his map and thus to exhibit a more realistic picture.

There is such a diversity of cartographic technique for mapping both population distribution and density that, from a single set of data, maps of different appearance can be made. Some of these techniques may be more suitable for showing the distribution, while others may be more suitable for portraying the density pattern. Difference in the choice of dot size and value, density intervals, use of true density boundaries and administrative limits, will result in different degrees of refinement on the map. It is almost always the case that only one map version among a variety which could be produced is presented. The kind of technique which the cartographer used to produce a special type of map will depend to a large extent on the purpose of the map. Also the map scale and the nature of the data are important factors affecting the choice of technique.

Brevity on maps implies a simple design of graphic symbols and a good balance in the general outlay of the cartographic presentation. On the one hand, simplicity contributes to the aesthetic beauty of the map and on the other, it enables the map user to extract quickly the essential patterns or information being portrayed. Even when presentation of detail is required, a judicious selection of dot value, tonal

patterns, density intervals, background information is extremely important. An overcrowded map always creates a mental barrier because the superfluous detail present obscures the amount which can be accommodated by the eye and comprehended by the mind. It is a truism that simplicity and legibility are synonymous.

Urban and rural populations possess distinct characteristics of their own. The degree of contrast in their magnitude and the mode of distribution are significant. Urban population tends to concentrate in large number in nodes, but rural population is usually dispersed in small groups over a wide area. To portray this sharp contrast and extreme distributional range in distribution maps, the use of dots and diagrams such as circles, cubes and spheres is necessary. Dots are most suitable to represent small quantities and readily display a dispersed pattern. Proportional symbols, on the other hand, suggest concentration and are able to portray large quantities. When these two types of symbol are used on the same map, they reveal not only the magnitude of these two basic components of population, but also their distinct characteristics. Among the distribution map series in this study, the one using dots and spheres serves this purpose very well. In addition, owing to these peculiar characteristics involved, in compiling density maps, the rigid use of mathematical systems or statistical processes for establishing density intervals is not suitable. The more satisfactory method is the rational process by which the map compiler can stress the characteristics of the data and show them on the map.

As has been learned through experience and experiment, maps with

symbols constructed with mathematical precision are not necessarily comprehended accurately. This is really a dilemma to the cartographer who strives to present a correct picture of the population data by means of symbols. Which one is more important to him, mathematical precision or visual accuracy? As a matter of fact, maps are a visual media of communication. Information in them is normally extracted by visual inspection rather than by mathematical measurement. Therefore visual accuracy is often to be preferred, even at the expense of mathematical precision.

There seems to be no shortcut for revealing the characteristics of the original data in population maps. The cartographer has to study and analyse the data with great care regardless of techniques to be employed. He must then be able to display all the significant values on the map that can be readily grasped by the map users. A false picture would result if meaningless statistics are presented. Hence, good balance, aesthetic beauty and accuracy are not the only prerequisites for a successful map.

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APPENDIX A

STATISTICAL ARRAY OF POPULATION DENSITY

0.16	5.5	8.4	11.2	47.5
0.25	5.6	8.5	11.4	47.9
0.25	5.6	8.5	11.5	63.2
0.27	5.6	8.7	11.5	74.3
0.72	5.6	8.7	11.6	76.5
0.72	5.6	8.8	11.9	96.1
0.95	5.7	8.9	12.0	116.6
1.0	5.8	9.0	12.1	132.0
1.6	5.9	9.0	12.2	132.3
1.7	6.0	9.1	12.3	189.3
2.0	6.0	9.1	12.4	428.5
2.1	6.1	9.2	12.4	1776.7
2.1	6.2	9.2	12.8	4666.2
2.1	6.4	9.2	15.2	5109.6
2.3	6.4	9.2	16.0	6000.0
2.3	6.5	9.3	16.3	
2.4	6.6	9.4	18.3	
2.5	6.7	9.4	18.5	
2.6	6.8	9.5	18.6	
2.7	6.9	9.6	19.1	
2.9	6.9	9.7	19.2	
2.9	7.0	9.7	19.5	
3.0	7.0	9.8	19.5	
3.2	7.0	9.9	20.3	
3.4	7.1	9.9	20.5	
3.9	7.1	9.9	20.6	
3.9	7.1	9.9	21.3	
4.0	7.2	9.9	22.2	
4.0	7.2	10.0	23.2	
4.1	7.3	10.0	23.5	
4.2	7.4	10.1	23.6	
4.2	7.5	10.2	23.6	
4.2	7.6	10.2	25.5	
4.3	7.6	10.4	26.1	
4.3	7.7	10.4	26.4	
4.4	7.7	10.5	27.6	
4.4	7.8	10.7	30.0	
4.5	7.9	10.8	30.5	
4.7	7.9	10.9	30.8	
5.0	7.9	10.9	33.2	
5.0	8.0	10.9	37.9	
5.2	8.0	11.0	39.2	
5.2	8.0	11.0	42.1	
5.3	8.1	11.1	46.9	
5.3	8.1	11.1		
	8.3	11.2		

APPENDIX B

STATISTICAL ARRAY OF POPULATION DENSITY (NON-RECURRING) SHOWING THE RANGE OF FIGURES PRESENT IN EACH DENSITY GROUP DIVIDED BY THE MODIFIED SEPTILE METHOD (FIG.17)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
	0.16	4.3	7.2	9.7	12.8	30.0
	0.25	4.4	7.3	9.8	15.2	30.5
	0.27	4.5	7.4	9.9	16.0	30.8
	0.72	4.7	7.5	10.0	16.3	33.2
	0.95	5.0	7.6	10.1	18.3	37.9
	1.0	5.2	7.7	10.2	18.5	39.2
	1.6	5.3	7.8	10.4	18.6	42.1
	1.7	5.5	7.9	10.5	19.1	46.9
	2.0	5.6	8.0	10.7	19.2	47.5
	2.1	5.7	8.1	10.8	19.5	47.9
	2.3	5.8	8.3	10.9	20.3	63.2
	2.4	5.9	8.4	11.0	20.5	74.3
	2.5	6.0	8.5	11.1	20.6	76.5
	2.6	6.1	8.7	11.2	21.3	96.1
	2.7	6.2	8.8	11.4	22.2	116.6
	2.9	6.4	8.9	11.5	23.2	132.0
	3.0	6.5	9.0	11.6	23.3	132.3
	3.2	6.6	9.1	11.9	23.5	189.3
	3.4	6.7	9.2	12.0	23.6	428.5
	3.9	6.8	9.3	12.1	25.5	1,776.7
	4.0	6.9	9.4	12.2	26.1	4,666.2
	4.1	7.0	9.5	12.3	26.4	5,109.6
	4.2	7.1	9.6	12.4	27.6	6,000.0
Range	(0.16-4.2)	(4.3-7.1)	(7.2-9.6)	(9.7-12.4)	(12.8-27.6)	(30.0-6,000.0)

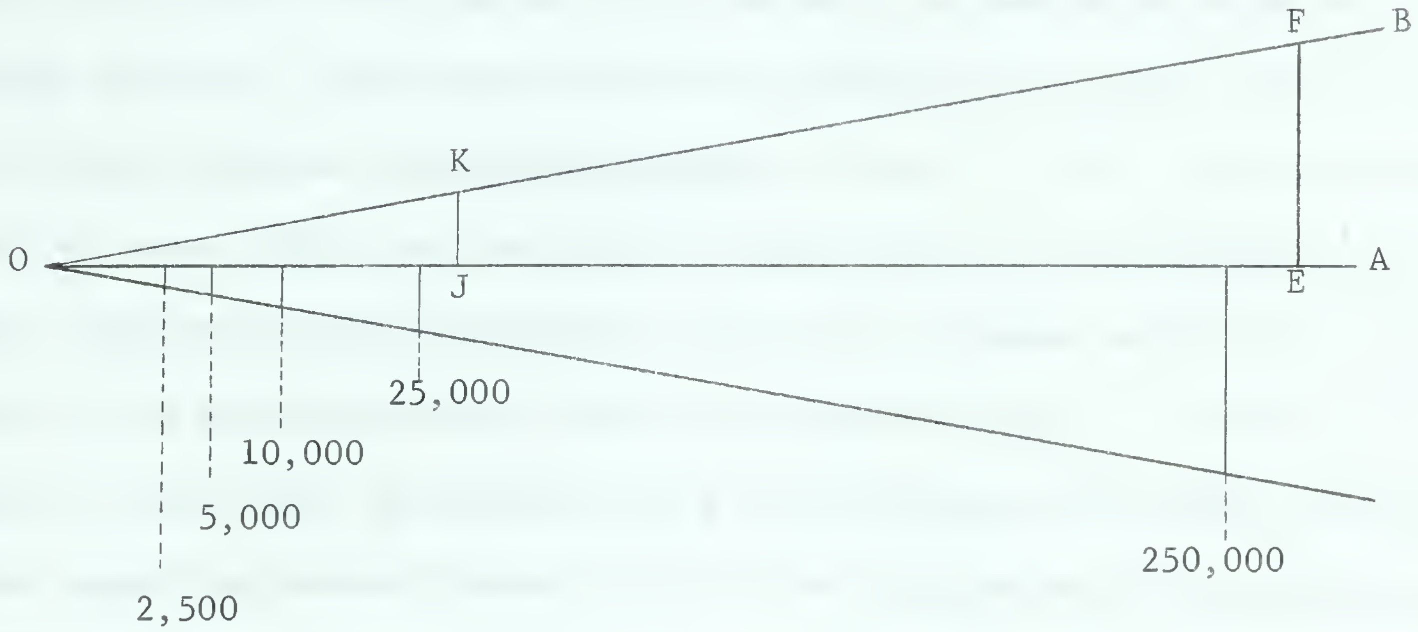
APPENDIX C

CALCULATION OF DIAGRAMS

	Population	Circles r^2	Spheres and Cubes $\sqrt[3]{p}$
Edmonton	281,027	299.08	64.0
Beverley	9,000	53.44	20.83
Jasper Place	30,530	98.55	31.25
Wetaskiwin	5,300	41.07	17.44
Devon	1,418	21.23	11.23
Drayton Valley	3,854	34.99	15.68
Fort Saskatchwan	2,972	30.75	14.38
Leduc	2,356	27.38	13.32
St. Albert	4,059	35.92	15.95
Stony Plain	1,311	20.35	10.95
Lancaster Park	2,125	26.01	12.85
Sherwood Park	3,000	30.95	14.42
N. Edmonton	4,620	38.35	16.66

APPENDIX D

CONSTRUCTION OF PROPORTIONAL SYMBOLS (CIRCLES) IN FIGURE 8



OA Base Line

AOB 10°

1. OE = $\frac{299.08}{60}$ inches $299.08 = r$ $\pi r^2 = 281,027$ (population of Edmonton)

EF = radius of circle representing total population in Edmonton.

2. OJ = $\frac{98.55}{60}$ inches $98.55 = r$ $\pi r^2 = 30,530$ (population of Jasper Place)

JK = radius of circle representing total population at Jasper Place.

APPENDIX E

PROPOSED SPECIFICATIONS FOR THE POPULATION MAP OF ANGLO AMERICA ON THE MILLIONTH SCALE

The base data specifications generally should be those applying to the International Map of the World (1 MW) on the Millionth Scale which are contained in the Proceedings of the Second International (Map) Conference, Paris 1913 with Amendments introduced by a Commission which met in London in 1928. These specifications, apparently, are still official and they were reprinted in World Cartography, Volume IV, 1954, United Nations, New York soon after the functions and assets of the Central Bureau had been transferred from Southampton to the U.N. To save repitition, the text of the specifications of the above-mentioned report is used as a point of departure; the several parts are referred to by number and comments made respecting each of these. For further details see the appended population map specifications and cartographic samples. Cognizance has been taken of two recent publications suggesting amendments to the 1 MW, neither of which has yet, to my knowledge, been officially accepted. These are, "A re-appraisal of the International Map of the World (1 MW) on the Millionth Scale" by (Colonel) Richard A. Gardiner, Empire Survey Review, Vol. XVI, No. 120 reprinted in the Internationales Jehrbuch fur Kartographie, 1961 (illustrated) and "Proposals for Amendments to the Specifications of the International Map of the World on the Millionth Scale Adopted by the 1913 Conference". This latter work, which contains two valuable appendices, (plates), was submitted by the Government of the Federal Republic of Germany to the United Nations Technical Conference

on the International Map of the World held at Bonn, 1962. Acknowledgement is made of the typescript specifications prepared by Wilbur Zelinsky for the Population Map of Anglo-America dated June 13, 1962 and September 20, 1963.

Index numbers and headings in the following specifications relate to those contained in World Cartography, Volume IV, 1954, United Nations, New York, Chapter 11, pp. 33-59 and comments pertaining to the Anglo American Population Map are made within this outline and in the Additional Specifications which follows:

1. Authoritative text of Resolutions - not applicable.
2. General Resolution - accept in principle but modify as indicated below
3. Area of each sheet - accept the areas as outlined on the map, "Suggested Layout for Proposed Population Map of Anglo America" by Wilbur Zelinsky.
4. Limits, Numbers and references of sheets. Limits: as in item 3 above; numbers: as in 3 above and on the list prepared by Wilbur Zelinsky: references (names): as contained in the list prepared by Wilbur Zelinsky.
5. Degrees, lines and margins - accept with modifications indicated by the enclosed samples and comments on these.
6. Projection - accept tables for the construction of the projection contained on pp. 42-47 in World Cartography, 1954.
7. Hypsometric colors and contours - not applicable.

8. Lettering - accept in principle but adopt new styles generally following Richard Gardiner's suggestions.

9. Spelling - accept on principle.

10. Conventional Signs (i.e. hypsometry, roads, railroads, city classification - not applicable) retain "A distinction shall be made between perennial streams and those which are sometimes dry."

11. Scales - accept parts a. (kilometer) b. (miles) but not c. (nautical miles).

12. Heights - not applicable.

13. International Boundaries - accept and see enclosed samples.

14. Preparation and Publication of Sheets - not applicable.

Additional Specifications

Since compilation scales may vary according to available source materials, the specifications outlined below for the Population Map of Anglo America apply to the reproduction scale of 1 : 1 million. Hence, material compiled at a larger scale must reduce to these specifications. Many of the following suggestions are exemplified by the enclosed samples: 1. Part of the S.E. corner of Sheet No. 33, Los Angeles; 2. General legend.

The samples indicated above are designed to facilitate the compilation of the map in centers where a minimum of cartographic equipment is available. Accordingly, instruments found in most Geography departments have been purposely employed. It is to be hoped that a complete re-drawing of the compiled sheets at one center, perhaps using

modern negative scribing techniques will be undertaken. If not, the sheets could be reproduced from the compiled material producing reasonable uniformity if these instructions are followed. The additional specifications apply especially to those items not covered in the general 1:1M specifications:

A.	Map Projection	Pelikan Graphos (m.m.)
	grid lines (including inner neat line)	A 0.1
	outer neat line	T 0.8
	numerals for grid	Leroy Template 120 Pen 00
B.	Scale (centered at bottom of sheet)	
	all lines	A 0.16
	distance between the scale lines	1.m.m.
	ticks extend upwards	0.5 m.m.
		Leroy
	Numerals on scale	Template #80
	wording on scale "1:1 Million"	Template #120
	wording on scale, "Miles, Kilometers"	Template #100
	for above thee templates - pen	000
	note: for length of scale, divisions of scale and spacing between scales and map, see sample	
C.	Rural Population Symbols	
	1 dot represents 50 persons dot size	Leroy #2 (0.26") or Wrico #6 (0.25")
	(For Military barracks cover barracks area solid as shown in samples).	

D. <u>Urban Population Symbols</u>

Proportional Circles
Formula: $R = .00075\sqrt{P}$
Where P is the population of city, etc. and R is the radius in inches (smallest circle - 1000 population)

Line width for circle (where very small circles are drawn it may be desirable to use a thinner line)	.25 mm
Five largest cities on sheet	Leroy
Initial letters in center of circle	Template #100
(regardless of urban tone pattern)	pen 000
note: A listing of these in the legend with total population (see example 2).	
Urbanized Areas	Zip-a-tone dot pattern Z 10

note: no line delimiting urban area; pattern used approximates that recommended in revised specifications for general 1:1M maps.
(Gardiner & Bonn Studies)

E. <u>Base Data</u>

Base Data		Leroy
Coastlines		pen 000
Rivers:		
	double (for each side	pen 000
	single up to (selection depends on area)	pen #1
	intermittent with spacing (see example for spacing)	pen 000
Lakes:	permanent (limits)	pen 000
	temporary (covering area, no bounding line). broken line pattern	Zip-a-tone #2360

Boundaries: (Width)	Pelikan Graphos	Leroy
International	A 0.6 for curves	#2
State	A 0.4 " "	0
County	A 0.16 " "	0000 (4/0)

(for spacing follow the samples which are broadly the same as for the general 1:1M, less dots)

note: Where boundaries follow rivers let the boundary take "visual" precedence over river - see sample 1.

Name of Sheet -	template - Cheltenham (open face)	Leroy #240 (c) pen 000

Note: see sample for spacing relative to top center, 6 mm above outer line. (for larger sheets e.g. #34 "Rio Grande" an appropriately larger Cheltenham template should be used.)

F. Marginal Matter

Legend material as on sample sheet 2 arranged as appropriate to the layout but with: Base data on left of graphical scale, and Map data (population) on right of graphical scale.

G. Insets

There is obviously much greater opportunity for insets on those sheets with extensive water bodies (ocean; Great Lakes), otherwise additional maps, etc., should be placed on the sheet margins. A good deal of liberty is allowed for these inset population maps respecting scale, treatment (even subject) depending on local needs and availability of detailed inset data.

APPENDIX F

COMPILATION PROCEDURE OF THE POPULATION DISTRIBUTION MAP OF ALBERTA

Except for some minor modifications, the proposed specification of IGU has been adopted in the compilation of the map.

Sources of data and information

1. Canada Population Census, 1961

2. Consultation with Regional Officer, Dominion Bureau of Statistics, Edmonton.

3. Topographic Maps -

a. Scale: 1:50,000, compiled by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, 1960 from air photographs taken in 1948 and 1957.

b. Scale: 1 in. = 4 miles, compiled in 1959 from aerial photographs. Drawn by the Forest Surveys Branch.

4. Air photographs

a. Scale = 1 inch to 1,500 feet - taken in 1961

b. Scale = 1 inch to 2,640 feet - taken in 1961

c. Scale = 1 inch to 3,333 feet - taken in 1949-51

Base map

Province of Alberta, Canada, prepared by the Department of Lands and Forests, 1962, at a scale of 1 inch to 16 miles. Projection: Universal Transverse Mercator.

Procedure of compilation

1. Tracing of the base map - The base map was traced on a dimensionally stable material. The details selected were international boundary

provincial boundary, hydrography, Indian reserves and corporate areas. The amount of hydrography shown had been chosen carefully with the consideration of providing a better orientation and at the same time avoiding congestion.

2. Preparation of a geographical array of the data - The number of people were transferred on to a transparent acetate sheet overlying a base map with enumerated areas shown.

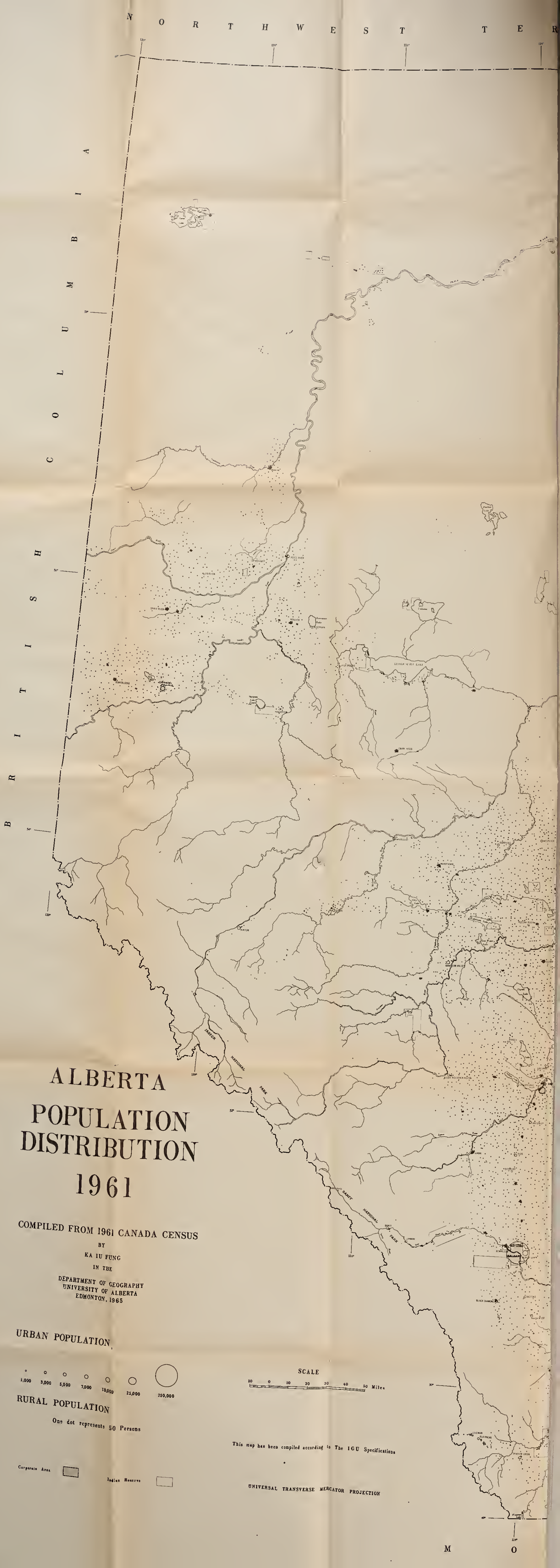
3. Calculating the number of dots in each township - The number of dots was calculated by dividing the number of persons in the township with the value specified. However, it was found that the number of people ascertained in each township very seldom equalled to 50 (the value of one dot) or a multiple of 50. Consequently, the value represented by the total number of dots would be less or more than the actual number of people present. The problem was solved by the following method. If the sum of the residual values left out from the contiguous township approached 50, a dot was added in the vicinity.

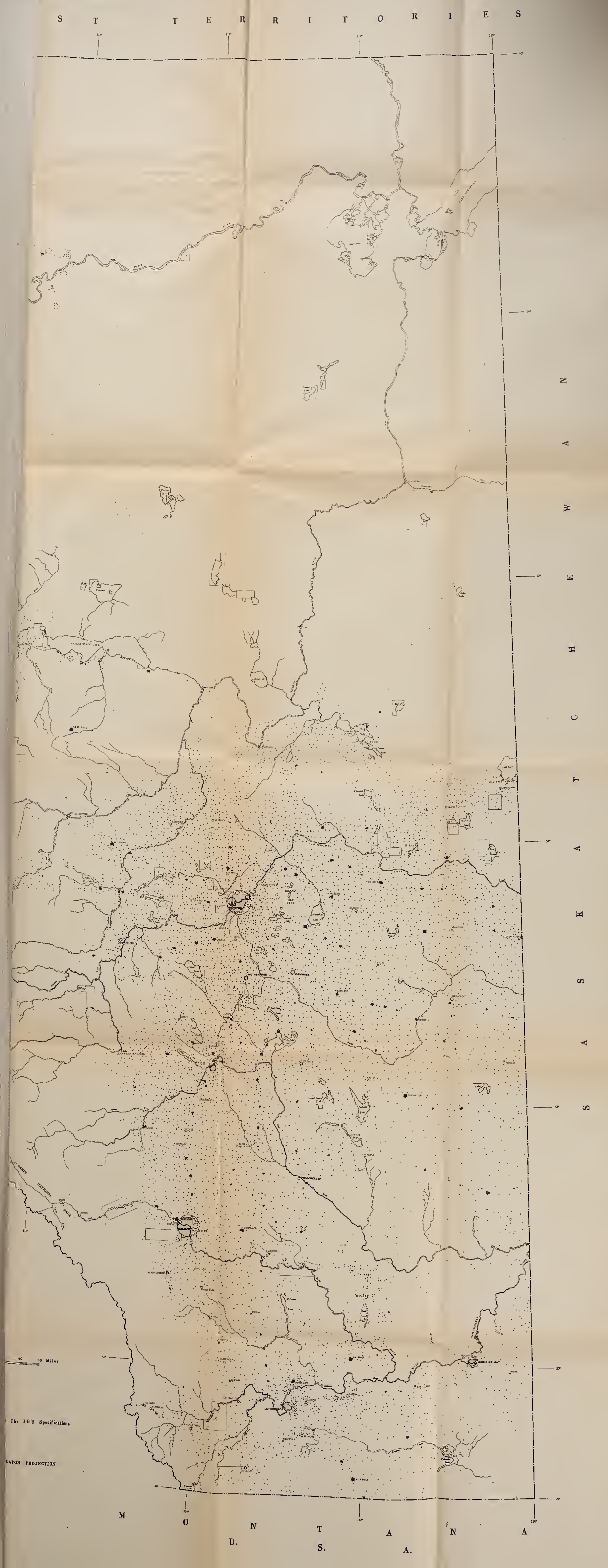
4. Dot placement - This particular stage was done in the office of the Technical Division, Department of Lands and Forests, where reference materials such as air photographs and maps are available. The distribution of farm buildings, hamlets and settlement structures on maps and aerial photos was used as a guide for placing the dots. The symbols were inserted as close as possible to the centre of gravity of the settlements. Difficulty arose when placing the dots in the Indian Reserves because of the mobility of the inhabitants. In some cases, no human structures of settlements could be discerned in either photographs or maps. Under such circumstances the dots were set uniformly inside the reserves, which helped

to show the number of people present though not their geographical location.

5. Plotting of urban symbols - The radii of the proportional circles were obtained from the specified formula $r = 0.00075 \sqrt{P}$ (r = radius, P = Population). For those small circles which were too difficult to draw, their size was enlarged five times and then reduced to the original size on positive photographic films. These symbols were cut out and stuck in place.

6. Map lettering - All the lettering of names of settlements and hydrography were obtained from the Technical Division, Department of Lands and Forests. Other letters for the title of the map and the legend were made by means of a Varigraph lettering instrument.


NORTHWEST TER
BRITISH COLUMBIA
ALBERTA
POPULATION
DISTRIBUTION
1961
COMPILED FROM 1961 CANADA CENSUS
BY
KA IU FUNG
IN THE
DEPARTMENT OF GEOGRAPHY
UNIVERSITY OF ALBERTA
EDMONTON, 1965
URBAN POPULATION
1,000
3,000
5,000
7,000
10,000
25,000
250,000
RURAL POPULATION
One dot represents 50 Persons
Corporate Area
Indian Reserve
SCALE
10 0 10 20 30 40 50 Miles
This map has been compiled according to The IGU Specifications
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
JASPER NATIONAL PARK
BANFF NATIONAL PARK
CALGARY
M O


S T T E R R I T O R I E S
S A S K A T C H E W A N
M O N T A N A
U. S. A.
40 50 Miles
The IGU Specifications
CATOR PROJECTION
EDMONTON
CALGARY
LETHBRIDGE
MEDICINE HAT